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A
DICTIONARY
OF
CHEMISTRY AND MINERALOGY,
WITH AN ACCOUNT OF THE PROCESSES EMPLOYED
IN MANY OF THE MOST IMPORTANT
CHEMICAL MANUFACTURES.

TO WHICH ARE ADDED A DESCRIPTION OF
CHEMICAL APPARATUS,
AND VARIOUS USEFUL TABLES OF
WEIGHTS AND MEASURES, CHEMICAL INSTRUMENTS, &c. &c.

ILLUSTRATED WITH FIFTEEN ENGRAVINGS.

BY A. & C. R. AIKIN.

VOL. I.

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DICTIONARY

CHEMISTRY AND METALLURGY

WITH AN ACCOUNT OF THE PROCESS OF MANUFACTURE

CHEMICAL MANUFACTURES

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BY A. C. C. N. ALKIN

VOL. I.

LONDON:

1807.

(The Author, Printer)

Bayerische
Staatsbibliothek
München

TO
CHARLES HATCHETT, Esq. F.R.S. &c.

WHOSE ADMIRABLE RESEARCHES IN THE SCIENCE
WHICH IT IS THE OBJECT OF THESE VOLUMES TO EXPLAIN,
HAVE RAISED HIS NAME TO AN EXALTED STATION
AMONG ENGLISH CHEMISTS,

THIS WORK

IS RESPECTFULLY DEDICATED, BY

THE AUTHORS.

Bayerische
Staatsbibliothek
München

P R E F A C E.

IN submitting to the Public a Work of considerable magnitude, the labour of some years, the Authors claim the usual indulgence of pre-engaging the notice of their Readers with a few words on its plan and object.

Their intention has been to give a faithful and sufficiently detailed description of all the important facts hitherto discovered in the sciences of Chemistry and Mineralogy, enlarging more particularly on those parts which are of peculiar interest to the Manufacturer and to the Practical Chemist.

Both the advantages and defects of the form of a Dictionary are sufficiently felt to render needless any observations on this subject; and the great encouragement which has been given in this and in other countries to this plan of describing the Arts and Sciences, is an ample proof of its utility and general acceptableness.

Though the compass of two quarto volumes would appear to allow ample space for a complete description of every branch of this science, the authors were convinced that they should either have been cramped in the parts on which they wished to enlarge, or have been compelled to extend their work to an inconvenient length, without some previous selection of the overflowing matter which lay before them. They have therefore omitted (not as being less interesting in itself, but merely as less suited to their particular purpose)

every thing relating to Geology, to the application of Chemistry, to Medicine or Physiology, to Galvanism, and to the History of the science, except to reclaim the merit of discovery in a few disputed instances for those to whom it appeared to be justly due; and they have made it a general rule to touch very slightly on the theoretical part of chemistry, that they might dwell on the practical. To render their labours useful as a *Laboratory Guide*, they have been studiously minute in most descriptions of analytical processes and elementary experiments, and they trust that their readers will not regret the pains that has occasionally been taken to reconcile the varying results of such chemists as Priestley, Klaproth, Kirwan, or Vauquelin, not by impeaching their general fidelity, but by shewing the inaccuracy of data on which their calculations have been founded.

With regard to the description of Chemical Arts and Manufactures, the intention of the authors of this work is not (had they the means) to teach their readers how to become iron smelters—glass-makers—soap-boilers—dyers—but to describe, as fully as they were able with the materials before them, the general principles on which these and other important chemical arts are carried on (with which the manufacturer himself is often but imperfectly acquainted) and by exhibiting the rationale of these processes to shew what parts of them offer the most reasonable probability of improvement.

Some new or hitherto unpublished matter will be found interspersed in these volumes, and particularly specified in the notes of reference to the respective articles. It relates chiefly to the description of certain manufactures, such as the smelting of copper, iron, and tin; the making of vitriol, common salt, sal ammoniac, and a few other processes, on which subjects the authors have been

favoured with original communications from friends on whose accuracy they can fully rely. They have also added the results of their own experiments on a few detached subjects that have engaged their attention.

The nomenclature which they have used has been in general that which is now become the vernacular tongue of scientific chemistry; but they have not in the least degree scrupled to blend it with the chemical language of Bergman, Scheele, Black, Beaumé, and a croud of other excellent chemists, whose works are rich with ever-valuable facts, and whose terms are still retained in shops and laboratories.

Such is the work now offered to the Public. They who have been engaged in similar pursuits will be able justly to appreciate the labour required in selecting, arranging, and comparing materials from voluminous transactions of learned societies, from long series of periodical works, and from the copious store of individual or elementary treatises with which this science abounds. The original authorities have been uniformly resorted to whenever the authors have had access to them, and when they have been obliged to use the medium of a Journal or Translation, care has generally been taken to express it in the notes of reference. By this means the reader may readily go over the same ground, and the Authors flatter themselves that such an examination will turn out favourable to the character of accuracy and impartial fidelity which it has been a principal object with them to acquire.

ERRATA in Vol. I.

Page 20, line 11	from the bottom,	for greyish clay, read greyish slag.
41,	14 from the top,	for durability, read ductility.
57,	8 from the bottom,	for unbedded, read imbedded.
118,	8, 10, 11, 12, from the top,	for X put +
120,	4 from the top,	for measures read increases.
—	11 ditto,	for descends read ascends.
127,	2 from the bottom,	for or, read of.
169,	25 from the top,	for it in, read in it.
237,	24 ditto	for with azot, read with hydrogen.
—	26 ditto	for hydrogen, read azot.
247,	19 from the bottom,	for 42.32, read 40.32.
357,	10 from the top,	for it, read heat.
359,	17 ditto	for return, read retain.
519,	7 ditto	for strong muriatic, read strong nitro-muriatic.

ABS

ABSORBENTS. ABSORBENT EARTHS.

The ancient chemists were accustomed to use the term Absorbents in a general sense, to denote all the alkaline, and such earthy bases, as were capable of absorbing or neutralizing acids. Chalk, magnesia, and clay, were however principally distinguished by this name, both on account of their easy combination with acids, and their mechanical absorption of water, and such other fluids as they do not combine with. Modern chemistry has almost discarded the term.

ABSTRACTION. *Abziehen*, Germ.

The process so called, consists in drawing off, by distillation, part of a compound, and returning it again, on the residue to be thus distilled over any number of times. It is used particularly in oxydating or acidifying substances by means of nitrous acid: thus, arsenic acid may be procured by abstracting arsenic with nitrous acid.

ACETOUS ACID. *Acid of Vinegar*. *Acide Aceteux*, F. *Effigsaure*, G.

As this important acid is, for the most part, though not always, the product of a fermentation consequent to the vinous, and formed of the same general materials, we have referred to the articles *Fermentation* and *Vinegar*, the description of the process of vinegar-making, and the rationale of this operation, and the domestic uses of this acid; we shall here therefore describe the chemical properties of the pure acetic acid, with its varieties and combinations.

ACE

The physical properties of pure acetic acid are the following: it is perfectly clear and colourless as water; its smell and taste refreshing and agreeable; and more or less sour and pungent according to the strength of the acid. The specific gravity of common distilled vinegar is about 1.006, but when concentrated in the method hereafter described, its weight is much greater, and by a particular process it may be brought to a solid and crystalline form.

The sources whence this acid may be procured are very numerous, more so than has commonly been supposed. It is found native in several vegetable juices, particularly in the SAP of various trees,^a and in that singular native animal acid, the acid of ANTS.^b It is procured not only from vinous fermented liquors, but from most mucilaginous, insipid, extractive animal or vegetable matters, when they turn sour by spontaneous change. Thus the moulding of starch, of moistened flour of any kind, of animal gelly, and even of urine, and the souring of milk, is in some degree a process of acetification, from the products of which, chemistry enables us to separate a certain portion of this acid, without a particle of alcohol (the test of vinous fermentation) having been generated. The action of fire upon these substances is a more immediate agent to the same effect, the valuable experiments of Fourcroy having proved that the acids of burnt wood, sugar or mucilage, and tartar, (commonly termed the pyroligneous, pyromucous and pyrotartareous) are no other

^a Vauquelin.

^b Fourcroy.

than the acetous, holding in solution a certain quantity of empyreumatic oil.

Lastly, the action of the stronger mineral acids upon the same vegetable and animal matters, tends to the production of the acetous acid, which is most strikingly illustrated by the final conversion into vinegar of all the intermediate and native vegetable acids, the malic, tartareous, gallic, oxalic, &c. The experiments that prove this interesting fact we shall presently relate.

Pure acetous acid is conveniently procured from common vinegar by distillation. The latter contains, besides acetous acid, a considerable quantity of foreign ingredients, such as alcohol, and particularly tartar, and the extractive mucilage, which gives it its red or yellow colour, and causes it to mould and lose its acid when long kept exposed to warm air. Of these the alcohol, the water, and the pure acetous acid, are the only volatile ingredients, and therefore separable by distillation. The distillation of vinegar is carried on in the large way by the druggists, for general purposes, and for the preparation of sugar of lead; in some parts of the south of France for the preparation of verdigris;^c with these it is distilled in a tinned copper vessel, as the action of vinegar upon tin is but slight. For the laboratory, however, glass vessels should be employed, or if the retort or boiler be of metal, the head or receiver should be of glass or earth. The strongest common vinegar is to be put into a glass retort with a receiver, and brought to boil on a sand bath. A watery and slightly acid vapour first condenses, which is a very weak acetous acid, and may be set aside. Then the distilled liquor (still continuing equally clear and colourless, but a little empyreumatic in smell and taste) becomes more strongly acid, and continues so to the last. This is the common acetous acid or distilled vinegar. Towards the end of the process, the residue is very apt to acquire and communicate a burnt smell and taste: this is prevented by carefully regulating the fire, and, if it be worth while, by adding to the liquor in the retort a little warm water; but when about five-sixths of it is distilled, the process should be discontinued. The residue is very sour, of a muddy brown red, and a strong pungent burnt smell. It contains, besides the remaining acetous acid, some tartar, and tartareous acid, and a slimy vegeto-animal matter, which has not been perfectly analysed. By further evaporation it becomes thick, tenacious, and at last a solid blackish extract. On urging

the fire to destructive distillation, it gives a sour empyreumatic inflammable vapour, an empyreumatic oil, and ammonia. The coal contains potash, mixed with a substance which gives oxalic acid in crystals when boiled with the nitric acid.^d The vapour of heated vinegar, or the acetous acid gas, as it has been termed, is inflammable.

The truly acid part of the purified acid is still mixed with a large portion of water. Means have been devised for condensing or concentrating the acid in a smaller bulk. Distillation alone, as we have seen, is not competent to this purpose; for, though some of the water rises nearly pure just at first, yet it soon becomes very sour, as the acid is almost equally volatile by heat as water.

The effect of frost in concentrating vinegar is very striking. If a quantity of this acid, distilled or not, be set out in the air in winter, when the cold is below about 26° a tender flaky ice forms in the liquor, and renders a large portion of it solid; on breaking it, a portion, still fluid, is found beneath, which is to be carefully drained off from the ice. This fluid is the acetous acid, concentrated by the loss of all the frozen part, which last is tasteless or very nearly so, and is little else than pure water. A further exposure of the strong acid to a sharper cold, will produce a similar and increased condensation, till at last the process must be stopped, either on account of the cold not being now sufficient to separate the water from the constantly strengthening acid, or from the ice itself becoming acid. Distilled vinegar may be brought by this mode of concentration from the common specific gravity of 1.006 to that of 1.029.^e In this state it still retains the physical properties of the watery acid, but in a much more exalted degree; its smell is strongly and agreeably pungent; its taste sharp, almost to causticity; and as a chemical agent, it is much more active and powerful in every respect. Common vinegar is equally strengthened by freezing, but as the colouring matter chiefly remains in the unfrozen part, it becomes more highly tinged as the more condensed.

A more effectual mode of concentrating this acid is by previous union with an alkali, an earth, or a metallic oxyd, and bringing it by evaporation to a solid consistence. In so doing, all the superfluous water of the acid is separated, and if the acid be afterwards expelled from the salt by means of a stronger affinity, it appears in the most concentrated form of which it is

^c Chaptal.

^d Gren. (System. Handbuch.)

^e Own Exper.

capable. Considerable difference of opinion has arisen whether the nature of the acid is essentially changed by this operation, or whether it is simply dephlegmated to the highest degree. This we shall afterwards notice, but we may observe that it is chiefly to its union with metallic oxyds that this question applies.

The first process of this kind was invented by Westendorf. It is the following: ^f saturate pure distilled vinegar with mild soda, filtre the solution, evaporate to a syrupy consistence, and suffer the acetited soda to crystallize. Dry the salt thus obtained, powder it, put it into a tubulated retort luted to a large receiver, add half its weight of strong and quite colourless sulphuric acid, and distill on a sand bath with a gentle heat, nearly to dryness. If it rises mixed with sulphuric or sulphureous acid, redistill it off a little clean clay.

This acid, which the inventor terms *alcohol aceti*, or *radical vinegar*, is excessively volatile and pungent, and also inflammable. However, it always contains sulphuric and sulphureous acid, from which it may be separated with great ease, by adding acetited barytes, as long as any white precipitate falls down.

The acid thus highly concentrated is crystallizable by cold. The Count de Lauraguais procured it glacial, when obtained from verdigris, in the way we shall presently mention; but Lowitz's experiments are still more curious.^g

This chemist first concentrated common wine vinegar by severe frost, distilled this in a water bath, surrounding the receiver with ice, and retaining only the latter portion of the product, which was by much the strongest. This last he redistilled from off some charcoal powder, to free it from empyreuma. This concentrated acid he exposed to the intense cold at Petersburg, of -22° Fahr. when part of it shot into crystals, leaving the rest uncongealed. These crystals when separated from the liquor, melted in a warm chamber, into an intensely caustic acid, which now, when again exposed to cold, congealed into a camphor-like white mass.

On account of the intense cold requisite for this process, it cannot be performed exactly in this manner in our climates; but the author gives another method which answers as well.

Mix and put in a retort two parts of dry acetited soda, with eight parts of dry crystallized *acidulous* sulphat of potash, and distill with a gentle heat. The process goes on speedily even in a weak fire, and two parts of a very strong acetous acid are obtained. By this method no

contamination with sulphuric acid is to be feared. This acetous acid in a temperature of about 38° , or a little higher than freezing water, shoots into either fine arborescent feathery crystals, or else into a confused striated mass. It remains unthawed till about 59° . It is much stronger than Westendorf's vinegar, is inflammable when gently heated and a lighted paper held to its surface, and burns with a gentle blue flame.

The acetous acid in every form, whether free or in combination, is completely decomposed by a low red heat, its acid properties destroyed, and it is reduced into its constituent parts; or rather, these parts form new combinations, from which the analysis of this acid may be satisfactorily inferred. The base or radical of the acetous acid appears to be compounded of carbon and hydrogen, mixed with a small quantity of azot. Hence it is that when the vapour of this acid is passed through a red hot earthen or glass tube, carbonated hydrogen, and carbonic acid gases, are generated in great abundance, and, owing to the presence of the azot, a small quantity of ammonia generally appears whenever this acid is exposed to destructive distillation. The combustion in close vessels of the dry acetites affords a similar proof of the composition of this acid. In an experiment made by Dr. Higgins,^h a quantity of acetite of lime, long dried in a heat of 212° , and giving no smell of acetous acid, was exposed to a gradual dry and destructive distillation, in an earthen retort, till the vessel was red hot, and every thing volatile in this heat was given out. After a small quantity of azotic gas had first come over, the products were carbonic acid gas, carbonated hydrogen, etherial oil, and aqueous vapour: the etherial oil passed off from the beginning, the carbonic acid throughout, and the carbonated hydrogen chiefly towards the end. The residue in the retort consisted of lime combined with much carbonic acid (which portion therefore had become fixed), and also blackened with some charcoal. On account of the variety of affinities which may readily be supposed to be mutually exerted on these easily combinable materials, at the impulse of caloric, the precise state and proportion of these ingredients, as they existed in the acid, cannot be deduced from the experiment, and even the presence of oxygen (independently of that existing in the water) would here be inferred only from the general analogy of acids. The carbonic principle is obviously the most prominent

^f Syst. Handbuch. ^g Crell. Annal. ^h Minutes, &c.

ingredient in this rough analysis, appearing in a variety of forms, both separate and combined.

The chemical composition of acetous acid is beautifully illustrated by the agency of the stronger mineral acids, both upon the hydrocarbonated bases of some of the other vegetable acids, and upon these acids themselves. Westrumb first discovered, that the acids of tartar and sugar, when boiled with nitrous acid, are converted into vinegar. The experiments of Hermbstaedt on this subject are highly interesting and instructive.

It had been discovered by Scheele, and confirmed by others, that spirit of wine, when treated with nitrous acid, was partially convertible into the tartareous and oxalic, or saccharine acids. Mr. Hermbstaedt examined this point with more attention.¹

He began by passing oxymuriatic acid gas from a pound of manganese, and a pound and a half of common muriatic acid, through a pound of highly rectified alcohol, which absorbed all the gas, and thereby became enlarged two-thirds of its bulk, and acquired a strong odour of nitrous ether. This was distilled till the product began to be acid; the residue was saturated with potash, and gave by evaporation muriat of potash and acetite of potash. Thus the production of the acetous acid from spirit of wine was proved, but to shew whether or not the alcohol previously contained any vinegar, further experiments were made. He took the gummy residue, left after the distillation of nitrous ether, or nitrous acid and alcohol, boiled it with some nitric acid, and obtained from the mixture much tartareous acid. Seven drams of this concrete acid were then distilled with one and a half ounce of nitrous acid; the distilled liquor was reserved, and the residue contained four drams of a concrete acid, which was now no longer tartareous, but chiefly saccharine acid. On twice repeating this process with the same quantity of nitrous acid, only half a dram of saccharine acid remained in the retort. All the liquors of the several processes were then redistilled together, and the product gave now only slight signs of saccharine acid, but when saturated with potash produced acetite of potash. Again, on dropping carefully one part of alcohol on three parts of nitric acid, much heat was excited, and bubbles of gas arose, which were chiefly carbonic acid, smelling strongly of vinegar. The same chemist varied these experiments in the following manner: two parts of dry acid of tartar were mixed with four parts

of manganese, and three of sulphuric acid, and distilled. The product was acetous acid mixed with the tartareous: on re-distilling it on the same materials, no other than acetous acid was now obtained. A similar result was given by oxalic acid, manganese, and sulphuric acid. Without the manganese the product is sulphureous acid, owing to the partial decomposition of the sulphuric, mixed however with the acetous.

The experiments of Dr. Crell are so similar to these above related, that we need not describe them particularly. In all, the acetous acid was produced in the way above mentioned, from the same materials.

The inference from these curious experiments is, that the radical of the tartareous, and oxalic, and we may add of many of the other vegetable acids, is the same, and that it exists in alcohol as well as in the native juices from which these acids are obtained. It is doubtless a compound of carbon and hydrogen, in certain unknown proportions. They are convertible into vinegar by the agency of the nitrous or the sulphuric, or the oxymuriatic acid, the operation of which the antiphlogistic theory will ascribe to the addition of oxygen, and perhaps at the same time the abstraction of a certain portion of the carbonaceous principle, which escapes in the form of carbonic acid.

We proceed to mention that variety of acetous acid, formerly known under the name of *radical vinegar*, and in the modern nomenclature termed (by some at least) *acetic acid*, in contradistinction to the *acetous*. It is procured by distillation of the metallic acetous salts, more especially the acetite of copper, or *distilled verdigris*; though there is much reason to suspect that the highly concentrated vinegar obtained by Westendorf's and Lowitz's method, from the alkaline acetites as above described, resembles the radical vinegar in every essential particular.

This may be procured in various methods: the following is the most ancient—Put any quantity of crystallized verdigris (commonly called *distilled verdigris*) reduced to powder, in a glass retort, with a large glass receiver; apply heat, gradually increasing, till every thing volatile has come over. The first product is a mixture of carbonic acid and hydrogen, about one-ninth part of the weight of the cupreous salt;² then appears a watery liquor a little sharp to the smell, but presently it becomes more and more acid, and at last excessively pungent and caustic, and of a greenish hue and somewhat

¹ Crell's. Chem. Annal. 1786.—J. Phy. Tom. 31.

² Darraeq. An Ch. T. 41.

coppery smell. This is the true radical vinegar, which should be kept apart from the former product in a well closed bottle. The residue is a red-brown oxyd of copper mixed with charcoal, which when the retort has been made red hot, to drive out the last portions of acid, often lines the inside with a cupreous metallic-looking pellicle. This oxyd is sometimes pyrophoric.

Another and more economical process is the following, given by M. Bâdolier:^k mix equal parts of sulphat of copper and acetited lead, distill as the last, but with a more gentle fire. A very pleasant and extremely pungent radical vinegar comes over, about a third of the weight of the ingredients used.^l No gas, except the atmospherical air of the vessel, is given out in this process, which is essentially the same as the former, since the perfect acetite of copper is first produced by the mixture of the two metallic salts, which mutually decompose each other, as soon as their affinities can begin to operate. The acetic acid procured from the salts of copper, is distinguished by a light greenish colour and a coppery smell, which makes an unpleasant addition to the agreeable pungency of the acid. It is not necessary to crystallize the verdigris in the first process, a solution of oxyd of copper in vinegar evaporated to dryness, will answer the same purpose. An acid similar at least in most sensible properties, may be obtained from the acetite of lead, not indeed by distillation per se, but by the addition of sulphuric acid, for none of the metallic, or alkaline, or earthy acetites, that have been subjected to experiment, will yield their acid, undecomposed by simple distillation, except the acetite of copper. Six ounces of sulphuric acid, added to twelve ounces of sugar of lead, and distilled with a gentle heat, will give seven ounces of a very concentrated caustic vinegar.^m In this however, as in most of those processes where the naked sulphuric acid is added, the product is contaminated towards the end of the distillation, by sulphureous gas arising from the partial decomposition of the acid by part of the carbonaceous basis of the vinegar.

Many experiments have been made, and arguments adduced, on the question of the difference of the acetic and acetous acids, but further facts are still wanting to enable us to decide with certainty. It appears reasonable that in making the comparison, we should only consider as proper acetous acid, simple distilled

vinegar, either in its common or watery state, or at most concentrated by frost, which to all appearance makes no other change than that of depriving it of a portion of its water. The acid, concentrated by distillation in any form whatever, either from the alkaline or metallic acetites, or by charcoal, or by the assistance of sulphuric acid, may probably be considered as the acetic, or radical vinegar, in one variety or other.

Distilled vinegar, strengthened simply by the freezing of its watery part, differs from the acetic acid of verdigris in the following sensible properties: its smell, though powerful, is much less pungent and stimulating, the vapours of the latter being so potent as almost to suffocate if strongly snuffed up, and to excoriate the nostrils and mouth: its taste shews the same difference of intensity: its specific gravity is not easily raised higher than about 1.029, whereas that of the radical vinegar is about 1.0404. When both acids are reduced to the same specific gravity by diluting the radical vinegar, the above difference in sensible properties is not very perceptible (the adventitious odour of copper in the radical vinegar prepared from verdigris, always being put out of the question) though some chemists assert that it is still to be remarked.

When saturated with either of the fixed alkalies, and brought to crystallize, the appearance of each salt is precisely the same. If an equal quantity of each be submitted to destructive distillation, the volatile products are so nearly the same as to allow of no assignable difference. However, the quantity of carbonaceous residue, according to Chaptal,ⁿ is less in the salt with acetic acid (or what, to avoid confusion, we shall for the present call the *radical* salt), than in the acetous; being only $\frac{1}{17}$ of the original weight in the former, and $\frac{1}{13}$ in the latter. But the experiments of Darracq,^o conducted in the same manner, are not so conclusive. Neither of these acids have any action on metallic copper immersed in them; the oxyd of this metal is dissolved by both, and furnishes a similarly crystallized metallic salt; with this notable difference however, that the radical acid dissolves the oxyd with much more facility, and the solution crystallizes much sooner and easier.

The acetous acid is in no degree changed by distillation with nitrous or oxymuriatic acid, so that it does not appear to be susceptible of a higher degree of oxygenation whilst in the

^k An. Ch. Tom. 37. ^l An. Ch. Tom. 41. p. 273. ^m Dölsch. Pharm. Ch. Erfahrungen. ⁿ An. Ch. Tom. 28. ^o An. Ch. T. 41.

form of vinegar. Radical vinegar is equally unchanged by this process.^p These and other experiments seem to decide the question, that the difference between the two does not depend on a different degree of oxygenation of the true acid base.

From the present state of our knowledge on this subject, we may take the following opinion as the most probable, namely, that acetous acid, though prepared from common vinegar by distillation, retains a considerable quantity of a soluble, mucilaginous, or extractive matter, which, without entering into the composition of the acid, or actually adding to its base, (though composed of the same materials) remains dissolved by the acid into a kind of saponaceous compound: that it still adheres to the acid in its various alkaline, earthy, or metallic salts, and opposes some obstacle to their crystallization, but that, when these salts are exposed to the action of heat, or of the stronger acids in close vessels, much of this extractive matter is separated from the vinegar either by forming carbonic acid, or by remaining behind in a carbonaceous state, and the acetous acid by this separation only, and not by any hyperoxygenation, becomes converted into the acetic, or radical vinegar. Hence it will follow, that in verdigris for example, the acid before distillation is still acetous, but during this process, the adhering carbonaceous extract turns to carbonic acid, by taking oxygen from the oxyd of copper, which last therefore is left nearly in the metallic state, whilst the acetous acid rises, simply freed from the extract which masked part of its acid properties, and appears in its purer form of radical vinegar.

Concentrated vinegar may be made to unite with alcohol into a true ETHER, though with more difficulty than the mineral acids.

Distilled vinegar does not dissolve any of the true resins, but has some action on the gum-resins.

It dissolves the acrid matter of plants, such as of the squill, meadow-saffron, &c. which is the composition of some medicinal vinegars. The solution is made by digesting the substance in ten or twelve parts of vinegar for a few days.

It thickens fat oils, and dissolves the essential in considerable quantity when concentrated. Mr. Westendorf dissolved eighty grains of oil of rosemary in four hundred and eighty grains of his radical vinegar. Common distilled vinegar has little more action on these oils than water. When mixed with the brown empyreu-

matic oil of burnt vegetable matter, it forms a peculiar modification of this acid, long known under the name of *pyromucous*, *pyrotartareous*, and *pyroligneous* acids. (For this see the next article, ACETOUS ACID. (*Empyreumatic*)).

Common distilled vinegar has little more action on camphor than water. The concentrated acid however dissolves it pretty largely. The camphor is mostly separable again by water.

The strong acid sparingly dissolves vegetable gluten. On starch it has no operation. Gum-arabic and the other mucilages readily dissolve in vinegar. A mucilage made with distilled vinegar may be used as a cement, like the watery mucilages, and with this advantage, that it is very little susceptible of mouldiness.

Jelly is first coagulated by the affusion of vinegar, and afterwards dissolved.

It coagulates the albumen of milk, blood, and serum, but does not dissolve it.

It shews a little action on animal gluten.

The uses to which the acetous acid in its purified state is applied, are not very numerous. The most important is in the manufacture of sugar of lead and verdigris. It is used largely in medicine. None of the acetites, besides those of copper and lead, are employed to any extent, except in pharmacy and in the laboratory.

The tests to discover the presence of acetous acid in any mixture, are not very obvious or direct. If the substance to be examined contains the acid in an uncombined state, it should first be saturated with an alkali, and evaporated very gently to dryness. Then the affusion of a few drops of sulphuric acid on a small portion of the residue, assisted by a gentle heat, will displace the acetous, and give the agreeable pungent acid vapour by which this latter is characterized. Afterwards if the quantity of materials be sufficient, the neutral salt may be dissolved out of the whole residue, and crystallized, and its nature thus detected by those who are skilled in the practical part of chemistry.

The order of the affinities of this acid are barytes, potash, soda, strontian, lime, ammonia, magnesia, alumine, and the metallic oxyds, (supposed to be in the same order as with the sulphuric acid.)

ACETOUS ACID. *Empyreumatic*.

A great number of vegetable substances when strongly heated in close vessels, so as to destroy their organization and texture, yield, among other products, a considerable quantity of a strongly empyreumatic, bitterish, pungent, sour

liquor, which is always more or less turbid and dark coloured; is incapable of crystallization, unites with alkalies, earths, and some metallic oxyds, forming, for the most part, brown and foul-looking compounds, generally deliquescent.

On account of some little variety in the taste, colour, and smell of these acids, when procured from different substances, they have long been distinguished from each other, and till of late, were considered as separate species.

They are the following:

1. *Empyreumatic Acid of Sugar, Syrupous Acid, or Pyromucous Acid*, which must be carefully distinguished from the acid of sugar, or oxalic acid, which is quite another substance. The pungent acid vapour of sugar, or any saccharine matter strongly heated, must be familiar to all who have ever entered a sugar-baking-house. Chemists have prepared this acid in the following method:

Put into a very large glass retort^a any quantity of pulverized sugar, of any kind, so as to fill only one-eighth of it, as the matter swells prodigiously in the process; adapt to it a large receiver, not closely luted, and heat it gradually on a sand bath. A vast quantity of gas arises when the sugar begins to scorch, which is mostly carbonic acid mixed with an inflammable gas, probably the gaseous oxyd of carbon. In the receiver is condensed a weak acid brown liquor, coloured by an oily matter, and also apparently fouled by a portion of fuliginous matter volatilized during the distillation. The quantity of acid obtainable in this process, varies according to the regulation of the fire, which should at least be pushed so as to make the retort red hot, and to reduce the sugar to a perfect charcoal, but in general about five-eighths of the weight of sugar may be obtained of the distilled acid.

Gum mucilage, manna, honey, starch, and other mucous or mucoso-saccharine substances, yield by distillation the same acid as sugar.

2. *Empyreumatic Acid of Tartar, or Pyrotartareous Acid*, also to be carefully distinguished from an acid of similar name, but totally different nature, *Tartareous Acid*.

To procure the pyrotartareous acid, distill any quantity of cream of tartar in a glass or earthen retort, as in the last process. The retort here may be half full of the tartar. On raising the fire very slowly, the first produce is a limpid acidulous somewhat bitterish water, after which, as the heat increases, a most prodigious volume of the inflammable gas is given out, together with a stronger acid and more empyreu-

matic liquid, and at last a black oil, and some volatile alkali. The whole quantity of liquid acid, procured from tartar in this method, is generally not more than about a quarter of the weight of the tartar, and is not quite so brown nor so highly empyreumatic as the former acid.

3. *Empyreumatic Acid of Wood, Ligneous, or Pyroligneous Acid*.

To procure it, distill as before, any quantity of shavings of any kind of wood, such as box, guaiacum wood, or beech, and an extremely strong-smelling dark-coloured empyreumatic acid liquor is obtained, nearly one-third of the weight of the wood. This acid is sourer, and also much blacker and more empyreumatic than the two former, probably as requiring a stronger heat for its production. The acid of wood is obtained in a large quantity near London, from the preparation of charcoal for GUNPOWDER, by distilling wood in cast-iron cylinders. It stains the hands deeply, and wood indelibly.

The three varieties of empyreumatic acid above mentioned, are all capable of very considerable purification by easy methods, and in proportion as they become purer, they lose their empyreuma, their peculiar taste and smell (and consequently their characteristic differences) till at last, when brought into the most concentrated state by some of the methods in which vinegar is dephlegmated, they all exhibit the characters of acetous acid in so unequivocal a manner that no doubt can now be entertained of their identity.

The varieties in the empyreumatic vegetable acids, were long ago thought to be accidental, and they had been referred to a common origin of a vegetable nature; but it is to one of the many valuable series of experiments with which Messrs. Fourcroy and Vauquelin have enriched the chemistry of organized bodies,^b that we owe the complete elucidation of this question.

Simple rectification or re-distillation in a very gentle heat, and stopping the process when the liquor at last comes over much coloured, will purify to a very great degree the pyromucous and pyroligneous acids: the latter, by this process, from being a dark coffee-colour, assumes the hue of very pale clear brandy. However on long exposure to light, it again becomes brown, for it retains its empyreumatic character more obstinately than the others. Charcoal, newly burnt and powdered, has a great effect in purifying all these acids: they may be either gently distilled off it, or even merely filtered through a stratum of it. But the most effectual method

of purification is by uniting these acids with lime, or a fixed alkali, evaporating to dryness, and then expelling the acid by means of the sulphuric, in the same manner as the concentrated vinegar is prepared. The acid vapour that rises in this process, has now lost its empyreuma almost entirely; has both the strength and the potent odour of radical vinegar; when again united to potash forms acetited potash, which may be obtained white by repeated crystallization, or by charcoal powder, and in short is perfect acetous acid.

The purified acid of wood has even been employed by Mr. Goetling, for the preparation of an acetous ETHER.

It has been mentioned that the colouring and flavouring matter in all these acids produced by fire, wherein they differ from the acetous acid, is an empyreumatic oil of greater or less intensity in taste and smell, which, as well as the acetous acid, is generated by the fire, and rises along with it, particularly towards the latter end of the process of distillation, when the fire is increased. Acetous acid then is a solvent for the dark-coloured empyreumatic oil of vegetable matter, and as a satisfactory proof of this, the above-mentioned French chemists succeeded in dissolving the oil in pure acetous acid, both by distillation, and more simply by merely shaking them together and digesting for a short time, and thus produced an *artificial empyreumatic acid*, sufficiently resembling those formed by destructive distillation.

The important combinations of these acids are so much identified with the acetites that they may be described together.

The pyroligneous acid alone is procured in such a quantity as to be an object for manufacture. At the best it is only an inferior acetous acid, and the difficulty of purifying it will forbid its profitable use in many of the arts to which vinegar is applied. However, as the process for procuring radical vinegar at the same time purifies this empyreumatic acid, it may probably be used for this purpose.

We may add that much of the acid from the distilled charcoal for gunpowder, near London, is employed by calico-printers in forming the acetited iron, used as a mordant, as here the colour and smell of the acid are in no way detrimental.

ACETITES. We shall here describe the salts formed by the union of the acetous acid with the several alkaline and earthy bases.

ACETITE OF POTASH, formerly *Terra foliata Tartari*. *Digestive Salt of Sylvius*. *Diuretic Salt*. *Regenerated Tartar*.

Much pains have been taken to prepare this salt for medicinal purposes, as it is one that demands great nicety of attention to be obtained perfectly white and pure.

Take any quantity of pure carbonated potash,^a boil it very gently with four or five times its weight of distilled vinegar added gradually on account of the effervescence; evaporate by slow ebullition, adding afresh distilled vinegar, till no more effervescence is excited. Then evaporate the whole slowly to dryness. A brownish uncrystallized salt remains. This is the acetited potash in its common state of purity, sufficiently so indeed for all medicinal purposes; but if it be required perfectly white, it is then to be melted without addition in its own water of crystallization, for a few minutes, over a moderate fire. This at first makes it darker coloured, and separates a black carbonaceous matter. Then re-dissolve the impure salt in warm water, and filter through paper. This solution should now be limpid, the colouring matter being left behind. Evaporate this solution to dryness, very slowly, in a glass or earthen pan, with frequent stirring, and the remaining salt will be nearly white, and is the pure acetited potash. This is a very tedious process, as one pound of the alkali will require, during the evaporation, nearly twenty pounds of vinegar to keep up the state of perfect saturation, the reason of which is, that much of the acid itself flies off with the heat, so that the vapours of this solution smell like those of mere vinegar. Though both the alkali and acid be as pure as can well be taken, the first evaporation to dryness always leaves the salt brown, except it be conducted at the last in the following manner: when the solution is of a syrupy consistence, continue to evaporate with great care, and in proportion as the salt separates from the solution, take it out with a glass or silver spoon, till almost all of it is thus obtained. This will be white. Mr. Lowitz also has found that an addition of powdered charcoal renders the solution limpid, and the salt resulting from it, white. The precise effect of the slight calcination, or rather aqueous fusion, in purifying the salt, is not easily determined, but as it is attended with a rapid loss of the acid, it should not be continued a moment longer than necessary.

A much better and more expeditious method is to employ, instead of common distilled vinegar, the same, concentrated by freezing.

The radical vinegar is still better, but more expensive.

This salt has a sharp somewhat pungent taste; it appears generally as a shining foliated mass (whence its ancient name *foliated earth*) but by a slow evaporation it may be brought to crystallize even from the common solution,^b and much more readily when prepared with radical vinegar. When crystallized it appears in thin compressed laminæ. It is very deliquescent in the air, so that it must be preserved in well closed bottles. It is soluble in nearly its own weight of water at a moderate temperature. Twice its weight of boiling alcohol dissolves it completely when pure. It crystallizes without much difficulty from the hot saturated solution.

Distilled per se, it gives no acetous acid, but is chiefly resolved into carbonated hydrogen, carbonic acid, and empyreumatic oil, along with some ammonia; the residue is carbonated potash. A solution of this salt long exposed to the air, moulds, loses its acid, and is finally resolved into little else than carbonated potash. The uncertain quantity of water in acetous acid, makes it difficult to estimate the exact proportions of ingredients in this salt; according to Wenzel, it is in the dry salt as 1 of alkali to .996 of concentrated or real acetous acid. Dr. Higgins^c found that four ounces troy (or 1920 grains) of pure salt of tartar, required for saturation 1900 grains of the strong acetous acid of 1.068 specific gravity (prepared on Westendorf's plan, by distilling acetited potash with sulphuric acid) and by evaporation even at a heat below boiling water, and not pushed to dryness, he calculates the alkali to part with no less than 572 grains of the acid, in becoming the crystallized terra foliata.

ACETITE OF SODA. (*Terra foliata crystallizata.*)

The preparation of this salt is easier than the last. To obtain it, saturate distilled vinegar with carbonat of soda, and evaporate with a moderate heat. If dried rather hastily, the salt is brown, but if the evaporation be stopped when the liquor is of a syrupy consistence, and cooled quickly, fine long spicular or striated bundled crystals are obtained, which are not deliquescent, but in a warm air fall to powder. According to Wenzel, the alkali is to the acid as 1 : 1.528 in the dry salt, and the crystallized contains 45.4 of water. It is soluble in about twice its weight of boiling alcohol.

The taste of this salt is somewhat acrid and bitter. Distilled, it gives nearly the same products as the acetite of potash, only the acetous acid is not quite so much decomposed.

ACETITE OF AMMONIA. (*Spirit of Mindereus.*) This salt is seldom seen but in a liquid state, and is usually made by adding distilled vinegar to carbonated ammonia, to saturation. About a pint of the vinegar is required to saturate half an ounce of the alkali. It is difficult to procure this salt in a crystalline form, as both the ingredients are nearly equally volatile, and rise with the watery vapour on the application of heat. However, by evaporating considerably this solution, and suffering it to cool in a dry cold place, some crystals may be obtained of a needled form,^d though at the expence of a large portion of the salt, which is wasted by the evaporation. Hence it is more economical for this purpose to begin by using the concentrated vinegar.

Another method is by sublimation, as observed by Laffone.^e The process is the following: put in a large retort equal parts of muriated ammonia and chalk, previously mixed together; pour on it the same quantity of radical vinegar, and distill with a gentle heat. An aqueous liquid first rises, then a copious white vapour, which presently condenses in the receiver, in a fine feathery or needled form. This is the crystallized acetite of ammonia.

The liquid salt is made economically, and of considerable strength, by the following process of Lowe,^f in which a mutual decomposition of muriated ammonia and acetited potash takes place. Saturate four ounces of carbonated potash with distilled vinegar, and evaporate the solution to the bulk of thirty-six ounces; add to this two ounces of muriated ammonia, and distill the whole in a gentle fire. The distilled liquid is the acetite of ammonia. It is obvious that this might readily be made more concentrated if required. The taste of this salt is much like the preceding, but with something peculiar.

According to Wenzel, 120 parts of concrete carbonat of ammonia require for saturation 229½ of radical vinegar; and estimating the real alkali of the ammoniacal carbonat at about 40 in 120, the proportion of real acetous acid to the alkali in this salt will be 240 :: 244. This salt is readily soluble in alcohol.

ACETITE OF LIME. Lime is entirely soluble in acetous acid; chalk easily; pure lime with difficulty. The solution is yellowish, and has a sharp and bitterish taste. By gradual evapora-

^b Pelletier. * Experiments on Acetous Acid. 1786. * Pelletier. * Mem. Acad. des Sciences, 1775. * Gren. Syst. Handb. VOL. I.

tion it leaves a spicular crystalline mass: a somewhat greater heat makes it rise up in cauliflower-like knobs. Left to spontaneous evaporation, it gives beautiful silky crystals, which most remarkably climb up the vessel in an elegant arborescent plumage of crystals, especially on the side exposed to the light. This salt is very soluble both in water and alcohol. According to Wenzel, the proportion of acid to the earth is as 240 :: 145.

ACETITE OF BARYTES. Carbonated barytes, procured in the method described under the article *Barytes*, is readily soluble in distilled vinegar. The solution slowly evaporated affords silken spicular clustered crystals. This salt is not deliquescent, has a bitterish taste, dissolves in 12 parts of cold water, and about $1\frac{1}{4}$ of boiling water, according to Buckholz.^s This is a very useful salt as a re-agent to free radical vinegar, or any other kind, from sulphuric and sulphureous acid, with which as it is often prepared, it is liable to be mixed. It entirely precipitates the foreign acid, and adds no other species.

ACETITE OF MAGNESIA. Carbonated magnesia readily dissolves in this acid. The solution dries to a sweetish, bitter, greasy uncrystallizable mass, very deliquescent, and readily soluble in alcohol. Wenzel gives the proportions of earth and acid to be as $123\frac{1}{4}$: 120.

ACETITE OF STRONTIAN. This has a sweetish, and afterwards a bitter, taste. It is scarcely known.

ACETITE OF ALUMINE. This earth is scarcely soluble by direct combination, except by long boiling, when by evaporation it leaves a whitish uncrystallizable mass. It is obtained by double affinity, especially by the mixture of alum with acetited lead. This forms a most important mordant for the calico-printers, and is the only one of the earthy or alkaline acetites at all used in manufacture.

ACETITED METALS. (For these see the respective metals.)

We shall add a few of the more useful double affinities subsisting between the acetites and some of the other alkaline and earthy salts, where an acetite may be conveniently made by double decomposition, as for instance, in forming acetited soda by the mixture of sulphat of soda and acetite of lime. We shall only give those in which the newly formed acetite remains in solution, and the other compound is mostly precipitated, either on mixture or at least after moderate evaporation.

Acetited Potash is decomposed by the sulphat of magnesia, and by alum.

Acetited Lime is decomposed by the sulphats of potash, soda, ammonia, and magnesia, by alum, and by all the alkaline and earthy phosphats.

Acetited Barytes is decomposed by all the sulphats.

Acetited Lead is decomposed by all the alkaline and earthy sulphats, and by the muriats.

For the other affinities of the acetites see the Appendix.

ACID. *Saure, G.*

All those substances which impress the organs of taste with a sharp, sour, and cooling sensation, are in common language denominated Acid. Both Nature and Art present us with many of these bodies, a few of which possess this character in so faint a degree as to be scarcely perceptible, while others are so strongly corrosive, as to require large dilution with water, before they can be safely applied to the living animal organs. From the power which acids have of combining with and dissolving almost all bodies, they are of first-rate importance and very extensive application to the various processes carried on in the laboratory: hence they very early engaged the attention of chemists, and have to the present time been the subjects of more experiments than perhaps any other substances.

Acids, according to the corpuscular theory, which explained all chemical phenomena by the mechanical action of the ultimate particles of bodies, were considered as a genus of salts composed of minute and sharp spiculæ, which readily penetrated into the minute pores of the substances exposed to their action, and thus separated their component parts from each other, while at the same time the acid became neutralized by having its points sheathed in the pores of the body with which it was mixed. The weakness however of this theory was demonstrated by Boyle, and by Stahl, in his work on salts; and the solvent power of acids was reduced by Macquer and his contemporaries to the general laws of chemical affinity.

A striking fault of the ancient chemists was their disposition to systematize and draw general conclusions from a few and incorrect experiments: hence they supposed that all combustible bodies were indebted for their common properties to the presence of a combustible element, called by them phlogiston or sulphur. In all the species of metals they recognized a common metallic principle, under the name of mercurial earth; so also they imagined that

there existed an universal saline element or principle of acidity common to all acids. Beccher affirmed this acid principle to be composed of water and earth, and therefore not entitled to rank as an element. Stahl was induced to believe that the sulphuric acid was the original one, of which all the rest were only modifications. A similar opinion was held by Sage and Landriani, except that the former supposed the phosphoric, and the latter the carbonic, to be the elementary acid. The discovery of oxygen gas in 1774, by Dr. Priestley, offered a new and most important substance to chemical investigation, which at length led to an entire change in the theory of the formation of acids. The illustrious Lavoisier, in 1778, presented to the Royal Academy of Sciences at Paris, a memoir on the acid of fugar, in which, after describing the method of preparing this acid from fugar and nitric acid, he concludes that the conversion of the nitric acid into nitrous gas, is occasioned by the loss of a portion of oxygen, abstracted from it by the superior affinity of the fugar, which last, in consequence of its combination with oxygen, acquires the characters of an acid. The same able chemist discovered soon after, that phosphorus, sulphur, and charcoal, when inflamed in oxygen gas, combine with the base of this air, acquire an additional weight, equal to that of the gas which disappears, and are severally converted into the phosphoric, sulphuric, and carbonic acids. Induced by these facts, he proceeded to generalize the inferences drawn from them, and maintained that the base of oxygen gas was the universal acidifying principle, which by combining with simple or compound combustibles, produced the various species of acids. This explanation has been generally acquiesced in, though some objections to it have lately been brought forward, founded upon the analysis of the Prussic acid, which appears to consist solely of hydrogen, carbon, and azot. The claim however of this substance to the character of an acid is very equivocal, as it neither tastes sour, nor alters vegetable colours. With equal or even superior propriety might sulphuretted hydrogen be placed in the list, as indeed it has lately been done by some German chemists, under the name of the hydrothionic acid.

Although every combustible body is capable of uniting with oxygen, it is not necessarily an acidifiable base; nor does this appear at all to depend on the inability of the base to combine with a sufficiently large proportion of oxygen,

for hydrogen when saturated with a larger proportion of oxygen than is required for any acid, produces only water. The developement of an acid is by no means to be considered as an evidence of the complete saturation of its base with oxygen, there being several acids capable of combining with additional quantities of this principle, and thence acquiring new and more decided acid characters. It is even supposed that some bases may be acidified in three several degrees, preserving in each distinct specific characters; hence results an important arrangement of these bodies as they are acidified in the first, second, or third degree. The reformed chemical nomenclature has ingeniously distinguished these states by the terminations *ous*, and *ic*, and the prefix *oxy* (for oxygenated). Thus sulphur at the lowest state of oxygenation at which it acquires acid properties, is called *sulphureous* acid; when still further oxygenated, it becomes *sulphuric* acid: thus also muriatic acid, when raised to its highest state of oxygenation, takes the name of *oxymuriatic* acid.

The characteristic properties of acids are the following:

1. When taken into the mouth they occasion a sour taste.
2. They change certain vegetable blue colours to red, such as tincture of litmus, or syrup of violets; and restore the blue colours which have been turned green, or the red colours which have been turned blue, by an alkali.
3. They have a stronger affinity for alkalies than these have for any other substance.
4. They unite with earths, with alkalies, and metallic oxyds, forming the numerous and very important classes of neutral, earthy, and metallic salts.

The old chemists divided acids into mineral, vegetable, and animal, according to their supposed origin; this however is not only an inconvenient, but an incorrect method of arrangement, as many of these bodies are found in all the three natural kingdoms. Perhaps the following is as good a way as any other of exhibiting their names and composition.

I. Acids with simple radicals.

Sulphur . . .	{	1. Sulphureous
		2. Sulphuric
Azot	{	3. Nitrous
		4. Nitric
Phosphorus . .	{	5. Phosphoreous
		6. Phosphoric
Carbon		7. Carbonic
Molybdena . .		8. Molybdic

Tungsten . . .	9. Tungstic
Chrome . . .	10. Chromic
Arsenic . . .	11. Arsenious
	12. Arsenic

II. Acids with double radicals.

Carbon and Hydrogen	13. Acetous
	14. Acetic
	15. Tartareous
	16. Citric
	17. Oxalic
	18. Malic
	19. Gallic
	20. Benzoic
	21. Succinic
	22. Lactic
	23. Mucous or Saccholactic
	24. Camphoric
	25. Suberic

III. Acids with triple radicals.

Carbon, Azot, and Hydrogen.	26. Sebacic?
	27. Zoonic
	28. Uric or Lithic

IV. Acids with unknown radicals.

- 29. Muriatic
- 30. Oxy-muriatic
- 31. Fluoric
- 32. Boracic

V. Compound Acids.

- 33. Nitro-muriatic (Nitric & Muriatic)
- 34. Pyro-mucous
- 35. P—tartareous
- 36. P—ligneous
- 37. Formic (Malic & Acetic)

Acetic &
Empyreu-
matic Oil.

VI. Dubious acids.

- 38. Laccic
- 39. Bombic

VII. Acids destitute of Oxygen.

- 40. Prussic (Hydrogen, Carbon, and Azot)
- 41. Hydrothionic (Sulphur & Hydrogen)

ACID-HOLDER. An article of chemical apparatus, see Appendix, No. 1. at the end of Vol. ii.

ACIDIFIABLE BASE.

An acidifiable base is any substance, whether simple or compound, that is capable of uniting without decomposition with such a quantity of oxygen as thereby to acquire acid properties. The term itself was unknown in chemistry previously to the discoveries of Lavoisier on the

composition of acids; because those bodies that are now proved to be convertible into acids, by combination with oxygen, were supported by Stahl, and his followers, to be already acids united with phlogiston. Thus sulphur, which according to the present theory is a chemical element, and capable, by combination with oxygen, of being converted into sulphuric acid, was by the Stahlans considered as a compound of sulphuric acid and phlogiston.

ACIDULOUS.

This term is employed to express in general a slight degree of acidity, or an excess of acid in a compound salt: hence sulphat of potash, with excess of acid, is called *acidulous* sulphat of potash, or super-sulphat of potash. The reverse of this quality, or an excess of alkali in the composition of neutral salts, is usually denoted by the prefix *sub.* as *sub-borat of Soda* (common Borax).

ACIDULUM. *Acidule.* Fr.

This is a name which is given in the new nomenclature to a genus of native vegetable salts, consisting of potash supersaturated with an acid. We are at present acquainted with two species, the tartareous acidulum, or *acidulous TARTRITE of potash*, and the oxalic acidulum or *acidulous OXALAT of potash*.

ACRID MATTER OF PLANTS.

The peculiar biting acrid taste possessed by several of the vegetable tribe, has been supposed, though with little probability, to be a distinct principle, in general eluding chemical research; and not a mere quality of certain known parts, such as essential oil.

The acrid matter may be extracted in most instances by water, or weak acids, or alcohol. It forms the basis of several preparations in pharmacy. The vinegar of squills is an example.

As an object for the chemist it stands in the same situation as the **AROMA**, and its separate existence is equally dubious.

ACTINOLITE. See **STRAHLSTEIN.****ADAMANTINE SPAR.** See **CORUNDUM.**

ADHESION. This curious subject belongs rather more to another branch of natural philosophy than to chemistry. As far however as it is connected with the latter, it will be noticed under the article **AFFINITY.**

ADIPOCIRE.

The name given by M. Fourcroy to a peculiar spermaceti-like substance, procurable from a certain unctuous mass, into which most of the soft parts of animal bodies are converted by spontaneous change, under certain circumstances of temperature and moisture, and more especially

when protected from the free access of atmospheric air.

Chemistry is indebted principally to the industry and talents of M. Fourcroy, for what is known concerning this singular substance, so that its chemical history is of recent date, and it makes such an important addition to our knowledge in what has hitherto been the most defective part of chemistry, that of animal matter, that we shall examine it with some minuteness.

The history of the discovery of this substance lies within a small compass.—A very large burying-ground, belonging to the church des Innocens, at Paris, had for many centuries been the receptacle of a considerable part of the population of that metropolis.^a The method of depositing the bodies had long been to dig large pits from twenty-five to thirty feet deep, capable of containing from twelve to fifteen hundred bodies, which, when filled, were covered with a few feet of earth, and suffered to remain undisturbed for a longer or shorter time, that is from fifteen to thirty years, according as room was wanted. The average number of burials had been for many years about three thousand annually, so that the soil for many feet beneath an area of seven thousand square yards, was almost an entire mass of animal matter, which had gradually risen several feet above the natural level of the neighbouring ground. For nearly two centuries complaints had been made of the insalubrity of such an immense mass of putrefaction, within the heart of a large closely-built populous city, and at last, in the year 1782, the government undertook the formidable operation of removing the greater part of the soil, with all its contents. This business necessarily exposed to view the situation of these common burying-pits, in every different period of spontaneous change, and the observations of several able scientific men, assisted by the experience long acquired by the grave-diggers, enabled them to collect the following very interesting particulars.

In the first of these pits which was examined, and which had been filled up about fifteen years, the bodies were found sunken to the bottom of the coffins, as if they had been pressed down with a weight; on removing what remained of the linen shroud, the body beneath it was found converted into irregular masses of a soft unctuous cheese-like substance, grey brown in colour, breaking down under the fingers like spermaceti. The smell of the bodies thus

changed was not very offensive, so that they could be handled without much repugnance. On further examination, it was found that every part of the body, except the bones, nails, and hair, was converted, sooner or later, into this spermaceti-like substance; and by the evidence of the grave-diggers it appeared that this change was completed in these large receptacles in about three years, and that it was more perfect in the center of the pits than in the upper extremities, where the bodies were nearer the surface, and therefore more exposed to the action of the sun and air.^b Several varieties of texture and appearance of this substance were noted, sometimes quite dry and brittle, with a polished surface and a metallic lustre, at other times waxy, or soft as curd.

We shall not dwell further on the contents of this very interesting memoir, in which every particular that could be collected on so novel a subject, is detailed with great accuracy and apparent fidelity; we shall proceed to the chemical analysis of this substance.^c

Exposed to a heat not greater than boiling water, it melted, and by very slow distillation continued for many days, and regulated so as to produce as little decomposition as possible by the mere heat, it gave about one-sixteenth of its weight of a very fetid water, holding a quantity of ammonia in solution. The remaining mass was rendered somewhat more brittle by this process.

A long exposure to the air produced a similar effect in dissipating much of the alkali, and bringing the residue to a nearer resemblance to wax.

Its habitude with water shewed its saponaceous nature in a very striking manner. When rubbed in a mortar with a little cold distilled water, it readily and uniformly mixed with it, into a whitish emulsion, which, on adding more liquid, resembled exactly a solution of soap in water, frothed in the same manner by agitation, and was, like soap, curdled and decomposed by hard well water, by acids, by lime water, and by metallic salts. On filtering the solution, which took place very slowly, the clear liquor remained excessively fetid, and on long standing, left by evaporation ammoniacal phosphate.

Mixed with lime and a little water, a strong odour of ammonia was given out, together with a very fetid gas, and after heating and lixiviating, the residue was a mixture of the lime with the oily base of the subject of experiment, from which the lime was afterwards separable by muriatic acid, leaving a dry, combustible, un-

^a Thourct, J. Phys. tom. 38.

^b Fourcroy An. Chim. tom. 5.

^c Fourcroy An. Chim. tom. 8.

tuous, brittle, crystallizable, waxy matter, shining in its fracture, and now entirely insoluble in water.

The fixed alkalies operated like lime in displacing the ammonia, and formed with the unctuous residue a true soap.

Liquid ammonia added to it, and gently warmed, immediately dissolved it into a clear limpid fluid, afterwards a little opalescent when cooled.

The acids shewed a very powerful action on this substance. Concentrated sulphuric acid added to it yielded a gas, which M. Fourcroy describes as more repulsively fetid than any which he had ever experienced. The dilute acid acted with less vehemence, and uniting with the ammonia, and also with some lime which the fatty substance contained, formed the sulphats of ammonia and lime, and separated the same peculiar concrete oil which has been above described.

Nitrous acid acted in a similar manner, but with more energy. When the substance was pure no azotic gas was given out, but much carbonic acid. The concrete oil separated as before.

Highly rectified alcohol had no effect upon it when cold, but when heated to boiling it readily combined with a third of its weight into a brown transparent liquid, which on cooling again deposited in feathery flakes about seven-eighths of what it had dissolved. The remainder was recovered by evaporation, and appeared to be the purer concrete oil, unmixed with ammonia, the only part therefore soluble in cold alcohol.

From the above short abstract of a very full and masterly analysis, it will appear that the fatty matter to which animal bodies are converted by long inhumation in deep moist soil, is for the most part a very peculiar saponaceous compound, formed of a certain quantity of ammonia, united with a singular kind of concrete suet-like wax, hitherto undescribed, and to which M. Fourcroy has given the very appropriate name of *Adipocire*. The compound besides contains some phosphoric and other salts, of little import to the present subject.

This *Adipocire*, itself insoluble in water, is rendered miscible with it by its ammonia, or by the addition of any other alkali. It is separated from its neutral combinations by the dilute mineral acids, and partly by alcohol, and even in some degree by simple exposure to air. In its natural state it is however so thoroughly and intimately blended with water, that it constantly

loses weight by desiccation, and it is scarcely possible to determine when it has parted with the last portions of this fluid. Its colour is always brownish or yellowish, and though when much divided it appears white, it resumes in mass, part at least of its original colour. When perfectly dry it has a singular flexible but granular texture, almost crystalline, but with some varieties, so that sometimes it more resembles wax, sometimes spermaceti.

It is not merely however by inhumation that animal matter is thus changed. Immersion into cold water for some weeks will produce the same alteration, and with much more rapidity. Since the notice of chemists has been directed to the subject, various observations have been made of human bodies or other animals, which by accident have remained many days in cold running water, which have afforded a similar matter. The same is often to be observed in large dissecting rooms, where putrid flesh accidentally remains neglected in a quantity of cold water, and the experiment has been also tried with success by Dr. Gibbes.^c He staked part of the carcase of a cow to the bottom of a running stream, and in some months the greater part of it was changed into adipocirous matter. In making it in this manner, however, much of it is lost, being carried away by the water, which is constantly covered with a fatty pellicle for some distance, while the process is going on. The same chemist, in endeavouring to purify it for experiment in the large way, found that the fetid smell remained after simple melting and straining, but on the affusion of nitric or oxymuriatic acid, it entirely disappeared, and became by the latter nearly as white as bleached wax.

Another method of procuring small quantities of *Adipocire*, in a state very nearly resembling that produced by putrefaction, is to steep the lean of meat in a moderately dilute nitrous acid.^d In three days the texture is changed, it becomes white, waxy, and when taken out, gently melted and well washed, it exhibits most of the characters of *adipocire*. The nitric acid however appears to adhere to it with great obstinacy.

The resemblance between *adipocire* and *spermaceti* is so striking, that some characteristic differences are requisite to distinguish the two substances. *Spermaceti* and the purest *adipocire* obtained from the putrefaction of buried human bodies,^e are both smooth and unctuous to the touch, lamellar and brilliant

^c Phil. Transf. vol. 84.

^d Gibbes. Phil. Transf. vol. 85.

^e Fourcroy.

in fracture, not ductile, but easily crushed between the fingers. Heated, the spermaceti melts at about 133° , the other at 126° and after cooling, becomes more brittle. When very pure, the adipocire has no odour, that of spermaceti is faint but distinguishable. Both are soluble in hot alcohol, but in very different proportions, the adipocire requiring no more than two-thirds of its weight of this liquid, and the spermaceti sixteen times its weight. Both are separable from it by cooling, with some little differences of appearance. Liquid ammonia also, when cold, dissolves only the adipocire, and even when heated it scarcely has any action on spermaceti.

Other experiments make some slight differences in the congealing temperature of these substances. Dr. Bostock,^f found the adipocire made by nitric acid to congeal at 90° , Dr. Gibbes at 112° . Boiling ether dissolves about one quarter of its weight, which mostly separates on cooling.

The resemblance which adipocire bears to spermaceti, has suggested the idea of converting to some economical use the offal carcases of horses, and other animals which are not the food of man. The first process of making adipocire by immersion in water, is spontaneous, but the subsequent purification would probably demand much attention. It remains as a probable source of profit to the manufacturing chemist, and to the philosophic, a promising vein for future discovery.

ADOPTER. An article of chemical apparatus. (See the Appendix).

ADULARIA. See FELSPAR.

ÆDELITE. See ZEOLITE.

AERIAL ACID. The term given by Bergman to CARBONIC ACID Gas.

AES VENERIS, AES USTUM. Names formerly given to a preparation of copper and sulphur strongly calcined. It has only been known in medicine, and is now disused.

AETHIOPS, Antimonial. A pharmaceutical preparation, made by uniting the crude or black sulphuret of antimony with running mercury, till the latter is totally extinguished. It is therefore a mixture of the sulphurets of antimony and mercury.

AETHIOPS, Martial, or Lemery's Saffron of Mars, is iron filings so far rusted by water, as to be pulverizable, but still magnetical. It is employed in medicine. As a chemical preparation, see IRON.

AETHIOPS, Mercurial. A term given by

some chemists to mercury rubbed down, or *extinguished* by trituration with gum-arabic. It is only used in medicine.

AETHIOPS, Mineral. The black sulphuret of MERCURY, made by triturating equal parts of mercury and sulphur, and used in medicine.

AFFINITY. *Affinité, F. Verwandschaft, G.*

All the phenomena of nature may be ultimately referred to two kinds of motion, attraction and repulsion. Attraction may again be subdivided into that which takes place between bodies at sensible distances, including gravitation, magnetism, and electricity; and that which acts only at insensible distances, such as cohesion and chemical affinity.

Cohesion, or homogeneous affinity, is the attraction between the component particles of homogeneous bodies, as between two globules of quicksilver: when made to touch each other, they run together into one globule, and are mixed in the most intimate manner, without however undergoing any alteration in their chemical or physical properties.

Chemical or heterogenous affinity can only take place between dissimilar particles; and the change of properties which is the consequence of this combination, cannot in the present imperfect state of our knowledge be inferred from those of the elementary particles. As when quicksilver is added to melted sulphur, the result is a compound possessed of neither the colour, the splendour, the inflammability, the volatility, nor specific gravity of either of its constituent parts.

These two affinities are the great agents in all the operations of nature and art, which are referable to the science of Chemistry; not only as instruments of Synthesis, as might be supposed from the primary meaning of the term, but also as the sole means of analysis, there being no way of resolving a chemical compound but by exposing its elements to the action of stronger affinities than those which retain them in union.

The force of homogeneous affinity is peculiar for all the substances in nature; thus there is a striking difference between the cohesion of equal masses of iron, tin, and glass; and the cohesion even of the same individual particles varies remarkably, according to the quantity of heat with which they are either mixed or combined, as for example, in the particles of water in the state of ice, of water, or of steam.

The force of heterogeneous affinity is also peculiar; for out of the whole series of bodies which are capable of uniting with any given

^f Phil. Journal, Vol. 4.

body, there are no two whose force of affinity appears to be equal. This may in part depend on the respective differences of their cohesive attraction, but is no doubt principally owing to a real difference in the energy of their chemical affinity. Most substances exist in visible masses, and therefore under the influence of cohesion; but as chemical affinity takes place between heterogeneous *elementary particles*, it is obvious that these two attractions are always in opposition to each other; hence there is a priori a possibility, which is also confirmed by experiment, that the particles of one body may have an affinity for those of another, and yet on account of the superior cohesion of the two substances, the chemical attraction may be imperceptible. It is impossible therefore to ascertain whether every species of particles has a chemical affinity for all the other species, although it is for the most part the opinion of the best chemists that this is really the case.

Heterogeneous affinity may be conveniently divided into *simple*, where only two simple substances are concerned; *single elective*, where only three are concerned; and *compound*, where a greater number is brought into action.

Before, however, we proceed to enumerate the characteristic circumstances of each, it will be necessary to explain what is here meant by a *simple* substance. The ancients believed many bodies to be simple which the superior skill and knowledge of modern chemists have most assuredly decomposed; and there is no reason to believe that in any one case has chemical analysis been able to procure the real elements or simple constituent parts of substances. A chemical element, therefore, does not so much signify a body that is absolutely undecomposable, as one that has not yet been resolved. But there is another sense in which even bodies that are known to be compound may be considered as simple, and that is where they combine with other substances, without being themselves decomposed. Thus sulphuric acid, which consists of oxygen and sulphur, because it unites with earths, alkalies, and metallic oxyds, without being decomposed, may in these cases be considered as acting the part of a simple substance, and would no doubt have been so esteemed, if all our knowledge of this acid was confined to the phenomena which it exhibits when acting on the above mentioned substances. In this sense alone we use the term when speaking of chemical affinity.

Simple affinity takes place when only two species of particles, either really simple or at

least acting as such, are brought in contact with each other. In this case there are obviously two contending forces, that of cohesion tending to retain each species of particles in distinct masses, and that of composition or chemical affinity tending to blend, and intimately unite each particle of one species with one of the other. If both substances are solid, there will be no combination, whatever may be the strength of their mutual affinity, for the contact in this instance can only be superficial, and even this very imperfectly. Thus iron and sulphur, which in favourable circumstances will unite with great energy, are wholly incapable of action if each is in a solid form. Now the solidity or cohesion of a body may be reduced in two ways, either imperfectly, by mechanical means, such as pounding, cutting, filing, &c. or more completely by the application of heat, it being the uniform effect of this agent to enlarge the bulk and weaken the cohesion of all bodies that are exposed to its action. It is from long experience of the effects of cohesion in preventing chemical union, that the axiom has originated, that "bodies do not act on each other except they are liquid;" which, although like many of the old chemical maxims, it is not to be received without certain modifications, is yet, in many cases, strictly true: the efficacy of affinity being *ceteris paribus* inversely as the attraction of cohesion, and the fluidity of one at least of the substances, is in all cases necessary to chemical composition. An example of simple affinity is when quicksilver and melted sulphur are blended together. Here, the cohesion of the sulphur being weakened by fusion, and the quicksilver being also fluid, the quiescent force or attraction of cohesion, is unequal to the reciprocal affinity between the sulphur and the metal, which in consequence becomes efficacious, and combines the two into one body. All the cases of solution in which no decomposition of the menstruum or the solvent takes place, are examples also of simple affinity. Thus when common salt is thrown into water, the chemical affinity of the two being stronger than their respective cohesive attractions, a compound is produced in which the particles of salt water are no longer distinguishable by the eye, nor separable from each other by any mechanical force.

While a lump of salt is dissolving in water, it is obvious that the particles thus taken up will be constantly approaching towards an equality with those of the water, so that the mass of salt, every square inch of whose surface

was at first in contact with an equal area of water, is at length surrounded with a fluid of which the salt that it holds in solution forms a very notable proportion: therefore the particles of water in contact with any given surface of the undissolved salt, will be continually diminishing in number, and less able to overcome the cohesion of the salt; hence a period will arrive in which the cohesion of the undissolved salt, and the affinity of the remaining unsaturated particles of water, will exactly balance each other, and no further action will take place.

That solution is an instance of chemical agency, and not merely the diffusion of the particles of a solid through a fluid, is evident also from this, that water will dissolve very different proportions of different salts, which can only arise from the varieties in the force of its affinity; in certain circumstances also it will protect the substances that it holds in solution from the action of others, by means of its superior affinity for them.

It has been too much the custom in reasoning upon the more complicated cases of affinity, to overlook entirely that by which water or any other menstruum retains in solution the various objects of chemical experiment, and to consider a solution of salt for example, as the same thing with pure salt, only in a more convenient form, and hence have arisen many anomalies and errors.

Hitherto we have only considered the effects that take place when a single chemical affinity is concerned; we have now to treat of those cases in which there are two chemical affinities acting in opposition to each other. Common nitre is composed of nitric acid and potash; if to a solution of this neutral salt in water, we add a quantity of sulphuric acid equal to the nitric acid of the nitre; the sulphuric acid being incapable of combining with this salt, and having a strong affinity for the potash, its alkaline base, a decomposition of the nitre, is effected, and the alkali is divided between the two acids in the exact ratio of the strength of their respective affinities. The water then, instead of containing nitre and sulphuric acid, will hold sulphat of potash, with a small excess of sulphuric acid and nitrat of potash, with a large excess of nitric acid; but as the new compounds have at least as strong an affinity for water (or are equally soluble) as the sulphuric acid and nitre from which they are formed, they still remain intimately mixed with each other, and are incapable of being separated by

mere mechanical means. The affinity of the sulphuric acid for potash is greater than that of the nitric acid, and therefore in the experiment just recited, the sulphat of potash produced is greater than the quantity of nitre remaining undecomposed, since equal parts of each acid are supposed to be present. But the efficacy of affinity depends not only on the absolute force, but on the relative masses of the substances employed; we may therefore compensate in many cases the weakness of the affinity by a proportionate excess in quantity: thus although sulphuric acid has a stronger affinity for potash than nitric acid has, yet sulphat of potash, when treated with a large excess of nitric acid, is in great part decomposed, and may be made to deposit crystals of nitre. Hence it follows that the force with which any compound resists decomposition, is in the inverse ratio of the mutual saturation of its two elements; and that no compound how weakly soever its elements may be combined, can be wholly decomposed by the addition of any third substance, however powerful may be its affinity for either of the other two.

Till the late experiments of Berthollet on this subject, all chemists seem to have coincided with Bergman, who maintained that in cases where a compound was decomposed by the superior affinity of one of its elements for a third substance, there was a *total* transfer of the base from the substance of the weakest to that of the strongest affinity; and hence originated the term *single elective affinity*, which was made use of to signify that if to the compound A. B. a body C. was added, possessed of a superior attraction for A. than B. has, A. would by election or choice as it were, quit B. entirely, and form with C. a new compound A. C. to the exclusion of B.

In the example already given of the action of sulphuric acid on nitre, we have shewn that, though a decomposition is effected, there is no spontaneous separation of the different substances, on account of their ready solubility in the common menstruum; but in a great number of the cases of single elective affinity, one, and sometimes both the substances which are the result of the experiment, are so little soluble, that they separate spontaneously either wholly or in part, from the menstruum; or, in chemical language, are *precipitated*: and it is only by taking advantage of this superiority of the affinity of cohesion over that of composition, that we are able to procure in a separate state the elements of any compound.

Thus if to a solution of sulphat of potash in water, we add barytes, also dissolved in water, a-partition will be made of the sulphuric acid, between the barytes and potash; in consequence sulphat of barytes will be produced, and sulphat of potash, with excess of alkali: but the former of these salts being hardly at all soluble either in water or in alkaline sulphat of potash, will fall to the bottom, and the fluid will hold only the latter salt in solution. A fresh addition of barytic water will occasion a further precipitation of sulphat of barytes, till at length the liquor will come to be a solution of potash, with an imperceptible proportion of sulphuric acid and sulphat of barytes. Sometimes the whole contents of the fluid are precipitated, as when barytes is added to sulphat of zinc. Here the effect of the barytes is to divide the sulphuric acid, which was before combined wholly with oxyd of zinc, between the metal and earth, according to their respective affinities; and as sulphat of barytes and oxyd of zinc, with a little sulphuric acid, are insoluble in water, or in sulphat of zinc, both substances are precipitated, leaving only the undecomposed metallic sulphat in solution, which by a further addition of barytes, may be again decomposed and precipitated, till no greater quantity of sulphat of zinc is left than would form with barytes $\frac{4585}{40000}$ of the whole mass, because sulphat of barytes in this proportion is soluble in water: or in other words, the chemical affinity of water for sulphat of barytes, is to the affinity of cohesion between the particles of this salt, as 1 to somewhat less than 40000.

Compound affinity differs from single elective affinity in being more complicated. In the former a body is decomposed by the superior affinity of one of its elements for a third simple substance; in the latter a similar effect is produced by the addition of a compound body which is itself decomposed in the process. There are many advantages which this method of operating has over that by single elective affinity, and particularly that decompositions are much more complete, and require a smaller proportion of substances to be added in order to effect the proposed changes. Thus if sulphat of potash is to be decomposed by nitric acid, in order to procure crystals of nitre; if we merely add these two substances together, the affinity of sulphuric acid for potash being greater than that of nitric acid, a large excess of this latter will be required, and after all only a very partial decomposition can be effected.

We shall gain our end much more completely by previously combining the nitric acid with some substance that has as strong an affinity (or even stronger) for sulphuric acid, as nitric acid has for potash. If, for example, we make use of nitrat of barytes for this purpose, we shall attack the sulphat of potash, not only by the affinity of nitric acid for its alkaline base, but by that of barytes for its acid, and the concurrent action of these two powers will accomplish what neither separately could effect so entirely or by such small quantities. In the case here supposed, the sulphuric acid of the sulphat of potash, and the barytes of the nitrat of barytes, will combine with each other, and form sulphat of barytes, which will precipitate, while the nitric acid and potash being now at liberty, will combine eagerly with each other and form nitre. Hitherto we have only considered the *divellent* attractions, or those which tend to break the former combinations and produce new ones; it is equally necessary however to notice those which are called *quiescent* affinities, from their tendency to maintain the former combinations, and in consequence oppose all further change. Thus while the nitric acid and barytes are attracted towards the potash and sulphuric acid, this motion is opposed by the affinity that subsists between the nitric acid and barytes, and the potash and sulphuric acid, and it is only in consequence of the excess of the divellent over the quiescent affinities that any change takes place. Hence it is that there is no such reciprocal action in cases of compound affinity, as takes place in those of single elective affinity. Nitrat of barytes may be more or less completely decomposed, by the proper quantities either of potash or of sulphuric acid, as may sulphat of potash by nitric acid or barytes; or nitrat of potash by sulphuric acid, or barytes, or sulphat of barytes by nitric acid or potash. But nitrat of barytes being decomposable by sulphat of potash, no excess whatever of nitrat of potash can decompose in the smallest degree sulphat of barytes, because the quiescent forces are superior to the divellent ones, and must always bear the same ratio to each other, whatever be the proportions of the two compound substances.

The subject of chemical affinity has engaged the attention of the most able chemists from Bergman to Berthollet. Before the treatise of the latter philosopher, the opinion of Bergman had been universally adopted concerning the total change of base in all cases of decomposition; and many general laws and inferences

based upon this fundamental error were established, which the superior accuracy of Berthollet has shewn to be utterly groundless. The destruction of former errors, and a general view of the difficulties of the subject, and the proper method of experimenting, together with the enunciation of a few facts, which seem of very extensive application, comprise nearly the whole of the labours of Berthollet on this subject: it is therefore at present in an extremely imperfect state.

In the Appendix will be given Bergman's table of single elective affinities, together with the schemes of compound affinity, and Mr. Kirwan's table of the numerical strength of affinities; where also may be found some remarks on the authority to which they appear respectively to be entitled.

AGALMATOLITE. See BILDSTEIN.

AGARIC MINERAL. See BERGMILCH.

AGATE. See KALZEDON.

AGGREGATE, AGGREGATION.

These terms are at present but little used. Some chemists have employed the phrase Affinity of Aggregation, to express that force by which bodies remain in mass, and therefore without change, in opposition to the phrase Affinity of Composition, which is the same as chemical affinity. Hence they have distinguished two kinds of aggregation, homogeneous or cohesion, being the attraction that takes place between similar particles; and heterogeneous or adhesion, being the attraction between the external surfaces of masses. An aggregate therefore means a mass in general.

AGUSTINE.

By this term, barbarously compounded of Greek and Latin, and meaning, *without taste, insipid*, Professor Trommsdorf has distinguished a supposed new earth, discovered by him in the year 1800.

The mines of Johan Georgenstadt contain a mineral resembling the berill, which being analysed, yielded unexpectedly, a new earth, called by its inventor Agustine, from its forming insipid salts with acids.

This earth, when pure, has a great resemblance to alumine; combines very feebly with carbonic acid; hardens by exposure to fire, and is insoluble in water. It differs however from pure clay in the following particulars. It is insoluble in any of the three alkalis, whether caustic or carbonated, in the moist or dry way. It combines with acids forming nearly insipid salts. It is equally soluble after

induration by fire as before. With sulphuric acid it forms a salt of difficult solution, and perfectly insipid, but which by a slight excess of acid becomes soluble, and crystallizes in stars. Its acidulous phosphat is also very soluble; but its acetite is scarcely at all so.

These are all the facts as yet known concerning this substance, and they rest upon the sole uncorroborated testimony of Professor Trommsdorf.^a

AIGUEMARINE. See BERILL.

AIR. In that part of chemical enquiry which relates to the constitution of gaseous bodies, some of the physical properties of air (abstractedly speaking) require to be noticed, as they very materially affect the accuracy of chemical experiments. (*For these see the article Gas.*)

AIR Atmospheric. See ATMOSPHERICAL Air.

AIRS Factitious. The several species of permanent airs or gaseous vapours, which have been discovered by modern chemistry, have been termed indiscriminately *airs* or *gasses*. As the latter term is become the most familiar, we shall merely enumerate in this place the several species of air.

Air alkaline, see *Ammonia*.

Airs acid, of these there are several species.

— *Dephlogisticated nitrous*, see *Nitrous oxyd*.

— *Dephlogisticated marine*, see *Oxymuriatic acid*.

— *Vitriolic acid*, see *Sulphureous acid*; and for the rest see the respective acids.

Air fixed, or *mephitic*, *Aerial acid* of Bergman, see *Carbonic acid*.

Air phlogisticated, or *Atmospherical Mephitic*, see *Azot*.

Air inflammable, see *Hydrogen*.

Air heavy inflammable, see *Carburetted Hydrogen*.

Air hepatic, see *Sulphuretted Hydrogen*.

Air vital, *empyreal*, or *dephlogisticated*, see *Oxygen*.

AIR HOLDER. An article of chemical apparatus. (*See the Appendix.*)

ALABASTER. See GYPS.

ALAUNERDE, *Alum earth*, or *Pyritaceous clay*. *Argilla aluminaris bituminosa*, Wern. *Terre alumineuse*, Fr.

The colour of this mineral is brownish black, or dun blackish brown. Sometimes, though rarely, greyish black. It occurs amorphous in large strata, and is of a middle consistence between hard and crumbly. Internally it is generally glimmering, on account of a few scattered particles of mica, but is sometimes wholly without lustre. Its fracture in small pieces is

^a An. de Chim. tom. 34. p. 133.

earthy and even, but in mass is flaty, sometimes passing into flat conchoidal. Its fragments are irregular, blunt-cornered. Its streak has a feeble lustre. It is very soft, and may be rubbed to powder between the fingers; is brittle, and of very little elasticity. Sp. gr. according to Kirwan, 1.75.

When placed among burning coals, it generally blazes a little; and when moistened and exposed to the air in large quantities, it heats, and not unfrequently inflames. From 100 parts of it after torrefaction, Klaproth obtained 10 alum, 7.25 sulphated iron, 2.25 sulphated lime, and 1 sulphated magnesia.^a Alum-earth is found in Sweden, in Saxony, Bohemia, Hungary, and Austria, in all which places it is employed in the manufacture of alum.

Its oryctographical situation is in alluvial strata, where it occasionally forms very extensive beds. It alternates usually with slate clay, bituminous schistus, sand-stone, and other alluvial minerals, but especially with bituminous schistus and bituminous wood: it appears indeed to be a natural mixture of these two substances, the latter of which is not unfrequently dispersed through it. Sometimes pyrites and selenite are mingled with it, and these substances are often accompanied with native alum, hair salt, and mountain butter. The alum-earth itself, indeed, when exposed for a time to the action of the air, becomes covered with a mealy saline efflorescence, which may be recognised for native alum, by its styptic taste.^b

ALAUNSCHEFER, *Alum-slate, Aluminous Schistus. Ardoise Alumineuse, Schiste Alumineuse.* Fr.

There are two varieties of this mineral.

Var. I. *Gemeiner Alaunschiefer. Common Alum-slate. Argilla aluminaris schistosa vulgaris.*

Its colour is greyish or brownish black, sometimes a middle tint between greyish and bluish-black: the surface is not unfrequently iridescent. It occurs amorphous, or in the form of concentric balls. Internally it is either dull, or glimmering, or little shining with a common lustre. Its fracture is strait-slaty, passing into the earthy-uneven. It flies when broken into broad shivers: gives a dull black or grey streak; is soft, brittle, and but little elastic: and has a meagre feel. By exposure to the air it acquires a whitish efflorescence, and then has the sweet styptic taste of alum. Sp. gr. 1.8—2.5.

It is frequently penetrated by veins of quartz, and mixed with pyrites.

Alum slate is found in Great-Britain, Sweden, Germany, Hungary, and some parts of France,

and is largely employed in the manufacture of alum.^a

Var. II. *Glanzender Alaunschiefer. Shining Alum-slate. Argilla aluminaris schistosa nitida.* Wern.

Its colour is between bluish and greyish black, passing into iron black. It occurs amorphous or in balls. Its parallel fracture is generally shining, sometimes even much-shining, with a greasy lustre approaching to the metallic: its cross fracture is dull. Its fracture is thick, or thin, and for the most part curved, flaty: the fragments are shivery. It feels smooth: is half hard, brittle, and but little elastic. It is a considerably richer ore of alum than the preceding variety, and is found in the same countries, though not so plentifully.^a

ALAUNSTEIN. *Alum-stone. Calcareus Aluminaris, Wall. Pierre calcaire Alumineuse. Pierre Alumineuse de la Tolfa.* Fr. *Argilla Aluminaris Tolfensis.* Wern.

The colour of alum-stone is for the most part greyish or yellowish white, passing into Isabella yellow, or light-yellowish or smoky-grey. Sometimes also it is found of a tint between flesh and tile-red, or spotted with ochre-yellow. It occurs amorphous, in considerable masses. Internally it is dull, very rarely glimmering. Its fracture is fine-grained uneven, approaching on one hand to earthy, and on the other to splintery or obscurely conchoidal: when broken, it flies into indeterminate sharp-cornered fragments. It exhibits sometimes coarse granular, sometimes conchoidal distinct concretions. It is translucent at the edges: is half-hard, passing into hard; brittle; slightly adherent to the tongue; meagre to the feel, and gives an argillaceous odour when moistened. Sp. gr. according to Kirwan, 2.424.

When thrown on a red hot iron it hisses, gives out a black smoky, a slight sulphureous smell, and the remainder acquires a reddish colour. It does not effervesce with acids: before the blow-pipe it melts to a greyish clay.

According to Bergman's analysis it contains,

35 Alumine.
22 Silix.
43 Sulphur.

100

The result of Monnet's analysis was,

50 Alumine
40 Sulphur
— with a little Iron and Potash
90

^a Klaproth, *Analyt. Ess.* ^b Emmerling *Lehrbuch der Mineral.* ii. p. 436. ^c Emmerling *jj.* p. 441.
^d Emmerling *v.* *jj.* 443.

La Metherie^a is of opinion, that this mineral is principally alum superaturated with its earth, and therefore earthy and insoluble in water; an opinion which is singularly confirmed by the late analysis of specimens from La Tolfa, by Vauquelin,^b who found

43.92	Alumine
25.	Sulphuric acid
3.08	Potash
4.	Water
24.	Silex

100. . .

This is a rare mineral, being found only at La Tolfa in the States of the Church, in Tuscany, and Upper Hungary.

At La Tolfa the alum-stone is found in large strata, and large masses among compact iron-shot argillaceous lime-stone, and is mixed with lithomarga, fluor, and calcareous spars, and penetrated by veins of quartz. In Hungary, pyrites, native sulphur, and quartz, are often found dispersed through it.

A volcanic origin has been attributed to it, but apparently without reason, as the veins of La Tolfa have been traced into the Appennines.

It is an extremely valuable substance, being the material from which the pure Roman alum is prepared.^c

ALBUM GRÆCUM, an antient and absurd name given to the dung of dogs; formerly used for medicinal purposes, but now deservedly laid aside. As a part of animal chemistry however, the properties of EXCREMENT are not to be overlooked, being of no small importance in some manufactures, particularly in the preparation of leather, and in some of the processes connected with dying and bleaching.

ALBUMEN. *Albumine*, F. *Eyweistoff*, G.

One of the immediate constituent parts of animal bodies which is to be discovered in a vast variety of organs, and by its general uniformity and comparative simplicity of composition, deserves to be ranked among the more elementary substances, is that which has been properly termed albumen. It derives this name from being found in great purity in birds eggs, forming the clear, colourless, viscid fluid, called, when coagulated, the white.

White of egg is a clear, viscid, colourless liquid, with scarcely any taste and smell. Even when fresh it contains an excess of soda, so that it changes the blue of syrup of violets to green. It is perfectly miscible with any quantity of pure water.

The most striking property which characterizes this and the other liquid albuminous liquors, is its power of coagulating into a white elastic mass on the simple application of heat. A temperature of about 160° is sufficient for this purpose. The precise cause of this kind of coagulation is unknown, and it is one of the most singular properties that can exercise the attention of the chemist, being exclusively confined to this animal substance. It has been very erroneously attributed to the absorption and fixation of oxygen, for this process will take place equally soon in close vessels, and under circumstances where it is impossible to trace the smallest operation of the oxygenous principle. Carradori^a found that white of egg coagulated very readily under a stratum of olive oil, and during its fixation no kind of gas was either given out or absorbed. Neither was there any apparent difference of bulk between the fluid and the fixed albumen, for the level of the liquid by which it was confined in a narrow tube, did not alter in any degree by coagulation.

Scheele relates a circumstance, by which he infers (though not quite in a satisfactory manner) that coagulation depends on the chemical union of caloric. If two portions of white of egg, previously diluted with four parts of water, are separately mixed with carbonated and with caustic potash, and muriatic acid afterwards added, the solution in carbonated alkali will remain clear, whilst the other will deposit much of the albumen in white coagulated flakes. The reason he explains to be that during saturation of the caustic alkali with an acid, heat is given out, which immediately fixes the albumen, but no increase of temperature occurs with the carbonated alkali. The reason of previously mixing water with the egg is to prevent the heat generated by the mixture from becoming sensible.

If white of egg is mixed with as much as eight times its bulk of cold water, and well agitated, it does not coagulate with the same ease, but the albumen separates only gradually, in the form of tough pellicles, on the top of the liquid, successively produced.

All the acids coagulate this substance, the strong ones almost immediately. An excess of the mineral acids redissolves much of the newly formed coagulum, which is not the case with the vegetable acids. The addition of water to the clear acid solution, again precipitates part of the albumen; but if this is previously mixed with much water, the addition of the strongest acid only coagulates it.

^a *Theorie de la Terre*, ii. p. 215. ^b *An. de Chim.* tom. 22. p. 275. ^c *Lenz. versuch der Miner.* Emmerling, ii. p. 445. Kirwan's *Mineralogy*. ^d *An. Ch.* tom. 29.

The alkaline and earthy salts produce no change on liquid albumen, but the metallic salts coagulate it sooner or later.

The tanning principle produces coagulation, or rather a chemical separation, for when an infusion of oak bark is added to recent albumen, a precipitate is immediately formed.

Alcohol very speedily fixes albumen, even when much diluted.

Two other animal liquids contain fluid albumen in considerable quantity; they are the serum of BLOOD and MILK. The cheese or curd of milk agrees in every property with coagulated white of egg, and is separated from the watery part by the same means, only it is in a state of very dilute solution.

The morbid affusion of water in dropsy, is sometimes almost entirely albuminous.

The further analysis of albumen refers more particularly to its coagulated state.

The albumen of eggs,^b if exposed to a moderate heat, not exceeding that of boiling water, in a dry place, soon shrinks very considerably, and at the same time becomes very hard, brittle, yellow, and semi-transparent like horn; after which it undergoes no further spontaneous change. This horny matter, if digested in boiling water, in a few hours is softened, and becomes again white, like fresh coagulated white of egg, after which it may be kept in boiling water for many days, without further change. The water in which it has boiled is not altered by oak bark solution, but very slightly by nitro-muriate of tin, shewing that the long coction has only dissolved an extremely small portion.

With acids some peculiarities are to be observed, which are of use in the minutiae of analysis.^c

The sulphuric acid has very little effect on solid albumen, except heated, when the albumen is charred and blackened, as is the case with most animal matters in these circumstances.

When long steeped in cold muriatic acid, it gradually becomes of a dark purple or blue colour. This change takes place in eight or ten days, after which no further effect is produced for many weeks or months. Very little of the albumen is dissolved by this process. Nitric acid changes this colour to a yellow.

Immersed in cold nitrous acid, rather dilute, the albumen is gradually softened and opened in its texture, and if afterwards taken out, washed, and boiled in distilled water, it entirely dissolves into a pale yellow liquid, which assumes the form of a thick jelly by slow evapo-

ration, and is *now* again soluble in water. So that the effect of this powerful acid is to bring it nearly to the state of gelatin, and the watery solution is equally precipitable by tanning.

If the nitric acid be concentrated, or especially heated, the whole is rapidly dissolved with extrication of nitrous fumes, and prussic acid, forming as before a yellow nitrous solution. Ammonia added to these solutions turns them of an orange or red colour, without forming any precipitate, and the solution is now ammoniacal.

All the alkalies when caustic, readily dissolve albumen. The fixed alkalies boiled with it, produce a true animal soap, and during the process much ammonia is given out. This soap dissolved in distilled water and filtrated, gives a copious precipitate on adding the muriatic or acetic acid. This precipitate is at first viscid and yellow, and on chemical examination appears to be the original albumen, little altered in its properties, except by being rendered rather more soluble in water.

Albumen exposed, per se, to destructive distillation, affords some water, carbonated ammonia, a foetid empyreumatic oil, carbonated hydrogen gas, carbonic acid gas, and prussic acid. A spongy coal of a grey metallic lustre remains, which it is extremely difficult to burn to ashes, as the process is constantly stopped by a vitrescent coating which forms around it. From 500 grains of dry albumen, Mr. Hatchett obtained 74.5 grains of residue, of which 63.25 were mere coal, and the remaining 11.25 consisted of phosphat of lime, phosphat of soda, and a little carbonat of lime.

Liquid albumen putrefies with ease when exposed to a warm and moist air. It is not so however with the coagulated, for in this form it may be preserved, even though white and soft, for several weeks in water without becoming very putrid, or at all broken down by this process; and indeed the truly albuminous parts of the body are among the least alterable ingredients of the animal frame. No acid is generated by liquid albumen during its putrefaction.

From the experiments of the excellent chemist above mentioned, which make part of a most interesting series of research on the variety of organs provided for the covering or protection of the living animal, it fully appears, that albumen exists almost pure in the horn, nail, flexible shell, hair, feather, and similar organs; that no ascertainable difference can be detected between the albuminous part of these, and the coagulated

^b Hatchett. Phil. Transf. vol. 90. ^c Hatchett.

white of egg; that it is distinguished from gelatin chiefly by its difficult solubility in water, even when not so dense in texture as the firmest gelatinous organs, by its very slow putrescibility, and especially by its forming a true soap with the caustic alkalies, a property not in any degree possessed by animal gelly. See GELATIN.

The vegetable kingdom is not destitute of its albumen, though from being more abundantly found in the animal, it has been termed, when vegetable, *vegeto-animal*. Fourcroy^c observed this substance in the expressed juice of many of the cruciform plants, such as the cress, scurvy-grass, &c. in cabbage juice, and in general it may be presumed to exist in those vegetables that exhale a putrid odour when dead and exposed to circumstances favourable to putrefaction.

The fresh juice pressed from the leaves and stalks of these plants, is at first green and turbid, and therefore, as pure albumen uncoagulated is quite limpid, the colouring matter must be another substance united with it. This has been termed the green FECULA, and is separable to a great degree by filtration, and by mere exposure to the air for some hours. After this, if the clarified juice be now heated in boiling water, a grey coagulum is separated in small curdy lumps, which agrees with albumen in all its properties of coagulability by heat, solubility in alkalies, and ready putrescency without the intermediate formation of an acid.

A similar albuminous matter is found in wheat flour. If this is worked up with cold water in the hands, into a very tenacious paste, and a small stream of water is suffered to drop through the paste, agitating it all the while with the fingers, the water runs off it for some time quite white and turbid, till at last every thing soluble in this fluid, or miscible with it, is extracted from the paste, and a very tenacious GLUTEN is left in the hands. The white fluid, by rest, deposits the starch or fecula, and the supernatant liquid remains clear. On exposing this clear fluid to a boiling heat, a white flocculent coagulum separates, which exhibits all the properties of albumen.

In the animal kingdom, albumen appears to be one of the primary constituent principles, and its characteristic properties are, on the whole, sufficiently obvious to make it a very promising subject for research to the chemical physiologist.

ALCOHOL, or SPIRIT OF WINE. *Esprit de Vin*, F. *Weingeist*, G.

This is the constant and most characteristic product of the vinous fermentation, produced equally from all fermented intoxicating liquors, by the process of distillation.

When pure, alcohol has the following properties: it is perfectly limpid and colourless as water, has a strong penetrating agreeable odour, and a very hot fiery taste, which, however, speedily leaves the tongue; when shaken in a glass vessel, it shews very large bubbles, which almost instantly disappear. It is much lighter than water, oil, acids, or most liquors with which we are acquainted. The actual specific gravity varies very considerably, according to the means employed for its purification, so that the extreme term of levity has not been fixed with perfect accuracy. The weight of the lightest alcohol, procurable by simple distillation, without any addition, is about .825 at 60° of temperature, and by means, which we shall presently mention, it may be brought as low as .813, or perhaps still less. On account of its great tenuity and liquidity, it appears remarkably mobile when shaken.

Alcohol is incapable of congelation in any degree of cold, natural or artificial, which has hitherto been observed, and therefore it retards in a high degree the congelation of other liquors with which it is mixed. So, equal parts of alcohol and water require a cold of—6° to be frozen; and if any common fermented liquor be exposed to frost, only the watery part will at first freeze, whilst the spirituous portion remains in the liquid, and causes it to resist a much greater cold than before.

Alcohol evaporates with very great facility at a much lower temperature than water. Held in the warm hand, it soon flies off, producing by its evaporation (as by all conversions of fluids into the gaseous form) a degree of cold, which in this instance is very considerable. It evaporates long before it actually boils. The latter takes place when it is heated to about 165°, and this boiling point is higher as the spirit is more watery, so that brandy, a weaker spirit, boils at about 180°. The vapour, in condensing, exhibits on the sides of the vessel a peculiar long streak, which is very characteristic. Its readier evaporation than water furnishes an easy method of dephlegmating it, or depriving it of water, by the mere application of well regulated heat. When once pure, it is unalterable by any number of successive distillations, if without addition.

Alcohol when poured gently on the surface of water, will remain on its surface for a con-

siderable time, without mixing with it, so great is the difference of their respective gravities; but on shaking them together they rapidly unite, extricating numerous minute bubbles, and a degree of heat very sensible to the hand if a few ounces of each are used, and the vessel that contains them not too thick. At the same time a mutual penetration takes place, so that the space occupied by the liquors after mixture, is less than when separated. Hence too the specific gravity of the mixture is greater than the mean gravity of each liquor separately taken, which forms the foundation of many interesting experiments on the gravity of spirit and water, which we shall presently mention. The mutual penetration is shewn very strikingly in the following manner: procure a thick glass barometer tube, with a bulb blown at one extremity, capable of holding four or six ounces of water, pour down through the narrow end (holding the glass with the bulb downwards) about as much water as will half fill the bulb, upon this pour alcohol, coloured very red with litmus, or any other dye, without shaking the tube, and fill it nearly to the top, when the coloured spirit will be seen to rest on the surface of the water unmixed: mark on the outside of the tube the height to which the spirit reaches; then, stopping the open end with the finger, shake the bulb violently, so as to cause the liquors to mix; the glass will feel somewhat warm to the hand, and the level to which the mixed liquid rises in the tube, will now be found at least an inch or two lower than when unmixed.

Spirit of wine of almost any degree of strength, readily catches fire when a lighted substance is applied, the easier, the greater is the strength. It burns with a pale flame, blue on the outside, and white in the center, but so faint as scarcely to be visible in day-light. If the alcohol is highly pure or free from water, every particle of it is consumed, but if watery, the spirituous part only burns, and the fire goes out as soon as this is nearly consumed. It does not require any wick to be set on fire, but if a wick is used it is scarcely injured by the flame in contact with it. The burning glass will not kindle it. The combustion of spirit of wine has this peculiar circumstance, that it is unattended with smoke, or any kind of fuliginous vapour, so that the brightest metal plate held over it, is not soiled with the flame: neither does the residue of combustion contain any coaly matter, the whole products of this process being only carbonic acid and water.

The flame of alcohol may be beautifully coloured by the addition of various substances; all the salts of copper give it a fine emerald green; boracic acid, or borax, a greenish yellow; nitre and some other neutral salts, a dun yellow; and the soluble salts of strontian a deep blood red.

Spirit of wine is immediately obtained by the process of distillation from every species of ardent spirits. The latter again, are the products of a previous distillation of any liquor which has undergone the vinous fermentation, so that at least two distillations are requisite to obtain the purely spirituous part of vinous liquors. We shall refer to the articles *SPIRITS Distilled*, the many important observations to be made on the business of the distillery, and the manufacture of brandy, rum, and malt spirits; and shall here only describe the chemical process of *rectification*, or the preparation of alcohol from these spirits.

The simplest process is the following: Put any quantity of brandy or malt spirits, or rum, diluted with as much water, into an alembic, (and better furnished with a water bath, as described in the Appendix, though this is not absolutely necessary) join to it the refrigeratory, and distill with a gentle heat. The first product is invariably the strongest and purest. The spirit continues to come over colourless, but gradually diminishing in strength and purity, till at last it is so watery as no longer to take fire by a lighted match. After this, if the distillation be continued, the liquor becomes milky, scarcely spirituous to the smell, and of a sourish taste. In this process no advantage is gained by continuing it after the liquor is no longer inflammable, which happens when about $\frac{3}{4}$ or $\frac{4}{5}$ of the whole contents of the alembic have passed over. If the first fourth or third of the distilled spirit be set apart, it forms a moderately strong alcohol, and the remainder, one more dilute, which will serve for many purposes.

Simple distillation will therefore separate the alcohol of any ardent spirit from the water, colouring matter and accidental impurity, but there are two principles which are not entirely got rid of in this manner, they are, an empyreumatic flavour often given by a careless or too hasty previous distillation of the spirit, and a strong, often foetid oil, which the spirit has dissolved, either out of the cask in which it is kept, or from some of the materials of fermentation, or from intentional additions by the manufacturer. The flavour of this oil is best

perceived on rubbing some of the spirit on the warm hands, whereby it readily evaporates, and a stale nauseous smell, like the breath of drunkards, is left. The mere empyreuma, or burnt smell, goes off in a great degree by keeping in charred casks, but the oil more obstinately adheres.^b

The observations of Beaumé^c on this subject are valuable. This most accurate chemist remarks that many wines, and brandies made from these wines, are naturally more oily than others, and retain this flavour through successive distillations; the rich Spanish wines much more so than the French, and hence they should be avoided in the preparation of pure alcohol. A large and repeated dilution with water, and distillation after each dilution, will indeed very effectually separate the oil (as may be observed by adding water to the spirituous scented essences, which will make them turbid, and the flavouring oil will swim at the top), but this process is tedious and embarrassing from the quantity of weak liquid. Dilution with water, filtration through quick-lime in close vessels, and subsequent distillation, will answer very well if the quantity of oil is not too great; having been, as Beaumé observes, an old practice with the Parisian liquor-merchants, who, to escape the barrier duty on raw spirits, used to convert it into scented spirits by the addition of a little essential oil, and afterwards, by the above means, restore it to its original state of simple spirit.

Alum, sea salt, Glauber's salt, calcined bone, chalk, toasted crumb of bread, and many other substances have been added, during distillation, to keep down the oil, all of them with considerable but not complete success.

Alkalies and lime remove it entirely, but with some alteration of the spirit itself, as we shall presently mention.

Beaumé recommends the following judicious management in distillation, to obtain part of the spirit considerably freed from the oil: it is founded on the fact that the first portion distilled contains scarcely any oil, but the latter product is almost saturated with it. Heat brandy in an alembic as usual, and when about a quarter of the liquor has passed, set it aside, and continue the process as long as the spirit is inflammable. This latter spirit re-distill as before, separating the first from the last product. Still repeat the distillation on the last product of the foregoing process, as long as the first quarter of the product comes over tolerably

pure. Then mix all the first products together and distill, reserving the first half for the purest alcohol, and the last for ordinary purposes. Thus the oil is constantly concentrated into the latter distilled portions, whilst the first are obtained proportionably purer.

We have mentioned that simple distillation of alcohol, however often repeated, and only the first product reserved, will yield a spirit of the specific gravity of about .825 at 60°, but the highest concentration is given by the use of alkalies or lime, or in some degree by any salt which has a very strong affinity with water; and the two former have the additional advantage of destroying the empyreumatic oil, though the alkalies are apt, in return, to communicate somewhat of an urinous flavour.

Though both the carbonated and caustic alkalies have the effect of concentrating alcohol, a difference takes place in their action on this liquid. The carbonated alkalies are insoluble in the spirit, but the caustic alkalies completely dissolve in it. If to a weak spirit is added some dry carbonated potash, and shaken together, the alkali becomes dissolved only in the water of the spirit, and thus two liquors appear of very different specific gravity, and absolutely immiscible by agitation. The lower liquor is the alkaline solution, the upper the alcohol, now rendered stronger by the loss of the water, which the alkali has separated from it. If the alcohol alone be poured off, and mixed with a fresh quantity of dry carbonated potash, the alkali will again either entirely dissolve, or become pasty, according to the quantity of superfluous water left in the spirit; if there is none, it will remain at the bottom untouched.

This is a ready way of bringing alcohol to very great concentration without distillation, and would answer every purpose, if it were not that the dry carbonated alkalies (except the crystallized) all contain a certain portion of the salt, in a state sufficiently approaching to causticity to be soluble in alcohol; so that in the above process, the liquid swimming above the watery solution of carbonated potash, is not pure spirit, but a very weak solution of caustic alkali in alcohol. To obtain it quite pure, add one part of very hot dry carbonated potash (good pearl-ash will do) to about six or eight parts of alcohol, already brought to considerable strength by distillation, let them stand together for some hours, frequently shaking them, then distill with a gentle heat, and the first half or two-thirds of the product is the purest alcohol.

^b Collier Manch. Mem. vol. v.

^c Elem. de Pharmacie.

Or, with less trouble, add one part of the alkali to four parts of brandy, and distill after standing together for about a day; but the former process is the best.

Burnt alum, dried Glauber's salt, or decrepitated common salt may be very conveniently substituted for the carbonated alkali.

Hot, dry, caustic alkali is still more efficacious in separating the water from the alcohol, which, carefully distilled, is extremely pure. But caustic alkalies, as well as lime, decompose so much of the alcohol, in the way that will be afterwards mentioned, as to render it both a wasteful process and one that requires more care in conducting it.

By the above means the levity and proportionable dephlegmation of alcohol may be brought from the specific gravity of .825 at 60° of heat, to about .813° or perhaps still higher. Malt spirits yield as strong and pure an alcohol as wine brandy.

Various methods have been employed for ascertaining the strength of ardent spirit, but this is attended with more difficulty than might at first be imagined. Long habit will enable a person to judge with tolerable accuracy by the taste, and the frothiness and size of the bubbles when shaken, but this is obviously liable to error. The test of burning the spirit has long been used, and with proper precaution it may be brought to some degree of accuracy. It has been already mentioned that a very pure alcohol will burn away without leaving any residue, and that the weaker the spirit is, the more water will be left after combustion. In many countries this trial is actually performed in the following simple manner.^d A cylindrical silver cup, properly graduated and made for this purpose, is filled to a known height with the spirit, which is then kindled, and is suffered to burn till the flame goes out, after which the quantity of watery residue is noted. Pure alcohol leaves none, rectified spirit of moderate strength about 25 per cent, French brandy about 56, common good malt spirit about 65, and the like. The principal imperfection of this method, is the difficulty of always performing the experiment under similar external circumstances: and besides it is by no means proved that the combustion of compound spirits will follow the same rules as that of simple mixtures of alcohol and water. In this trial the residue still contains a portion of alcohol, the combustion ceasing before all the spirit is burnt off; but on the

other hand, some of the water must necessarily have been evaporated by the heat of combustion.

Another trial, though extremely incorrect, is to pour a few drops of the spirit on a very small heap of gunpowder, and kindle it. The spirit first burns as usual, and when the last portion is burning off, the powder explodes, if the spirit has not been too watery to leave the powder very damp. Cotton wool burns in like manner at the end of the combustion of the spirit, if not too damp. But it is well known that a little heap of powder drenched with even a strong spirit, will not take fire, and a large heap will explode if only a few drops of a watery spirit is used. Besides, these tests, were they accurate, would only indicate two degrees of strength, that which would fire the powder, and that which would not.

Another test, sufficiently accurate for a rough estimation of the strength of the spirit, is to shake it in a bottle with some dry carbonate of potash, and to judge of its strength by the quantity of water which the alkali attracts from it.

A spirit that swims in olive oil has sometimes been considered as proof, and this method is actually used in the manufacture of rum, but this test also only indicates two degrees.

The only mode of ascertaining the relative strength of every species of ardent spirit, with any considerable accuracy, has been by determining its specific gravity; and the high public importance of the subject in countries where the consumption of spirits adds a vast sum to the public revenue, has been the means of instituting many very interesting series of experiments to this purpose.

As our limits will not allow a complete notice of all that has been done on this subject in different countries, we shall principally confine ourselves to the very minute, accurate, and every way excellent series of experiments made for the Honourable Board of Excise, by Sir Charles Blagden, assisted by Mr. Gilpin, and published in the 79th and 82d volumes of the Philosophical Transactions.

Their object was to determine by actual experiment, the specific gravity of mixtures of different proportions of alcohol of a determinate strength, with pure distilled water at different degrees of the thermometer; and these experiments were carried to a minuteness much more than necessary even for the high duties now levied on spirits, where a trifling

^c Blagden Phil. Transf.

^d Leonhardi's Macquer's Worterbuch.

difference in strength becomes an object of attention.

It is assumed as a principle in the present mode of laying the duties, that all kinds of distilled spirits contain an equal proportion of real alcohol with a mixture of pure alcohol and water, brought to the same specific gravity, and therefore it is on the absolute quantity of alcohol in any mixture that the duty is levied. This position though sufficiently accurate for the purposes of the revenue, is not absolutely true; since ardent spirit will dissolve various substances, such as sugar, colouring matter, &c. the effect of which solution will be to increase its density, and therefore to make it appear to contain less alcohol than is really the case.

The whole expansion of alcohol^a as pure as simple distillation will give, when raised from the temperature of 30° to 100° is about one-twelfth of the bulk which it had at 30°; and within this range the expansion is pretty equal for equal increments of heat. On the other hand, the expansion of water within the same range of from 30° to 100° is only $\frac{1}{145}$ of its bulk at 30°. Besides, a curious property of water, discovered by Dr. Blagden, here comes into action, which is, that (contrary to the nature of all other known liquids) it has arrived at its greatest density much before it is cooled down to its freezing point, namely at 40° or 42°, and that between this temperature and 30° its specific gravity regularly goes on diminishing till congealed. So that the gravity of water at 30° is found to be no more than at 48½°.

When alcohol and water are mixed, a mutual penetration of the two liquors takes place, as we have already mentioned, and the liquors occupy less room mixed than separate, so that the specific gravity of the mixture is greater than the mean specific gravity of the two, before mixture. The anomaly in the action of heat on water below 42° has just been noted, but another source of complication in calculating the densities of spirit and water, arises from the following circumstance: with a heat gradually raised from 42° upwards to 100°, water at first expands slower in comparison to

its entire increase, than alcohol; but afterwards, when approaching to the highest term of heat, its expansion is proportionably greater than that of alcohol. Hence it is that a mixture of these two liquids will approach the nearer to the progressive ratio of expansion of the one or the other, in proportion as one or the other liquor predominates in the mixture. But, again, the absolute expansion will be greater as there is more alcohol in the mixture.

All these circumstances indicated the danger of trusting to mere calculation from a very few data (as had been done by other scientific persons) to compose tables of the expansion of alcohol and water, with even tolerable correctness; and hence Sir C. Blagden, and his coadjutor, determined to undertake so many actual experiments on the specific gravity of mixtures of alcohol and water, at various temperatures, as to leave but very little room for incorrectness in the spaces on the scale filled up by interpolation. The pure, or standard alcohol, was that of .825 at 60°, being the purest obtainable by simple distillation, lowered a very little by water to bring it to even numbers for the convenience of calculation. The specific gravity was taken, in every case, by filling the same bottle to a known height with the spirit, and weighing it. To ensure a perfect penetration of the spirit and water, they were never used till they had been mixed for a month, and often shaken. The extreme precautions taken to ensure as great accuracy as human instruments can command, are given in detail in the original memoirs. The actual experiments were, the specific gravities, first of the pure spirit, then of 100 parts of it (by weight) with every five parts of water, from 5 to 100, and lastly of 100 parts of water with every five parts of spirit; all of them taken at every fifth degree of heat, from 30 to 100. The intermediate degrees, both of temperature and of proportion of water or spirit, are filled by interpolation.

The following Table, extracted from Mr. Gilpin's corrected tables, in the 82d vol. of the Philosophical Transactions, will apply to most cases which may be wanted in chemical enquiry.

• Blagden.

TABLE of the Specific Gravity of Mixtures of Alcohol and Water, at different temperatures.

One hundred parts (by weight) of pure Alcohol
with

Heat	Pure Alcohol.	5 Water	10 Water	15 Water	20 Water	30 Water	40 Water	50 Water	60 Water	70 Water	80 Water	90 Water
40°	.83445	.84539	.85507	.86361	.87134	.88481	.89617	.90596	.91428	.92151	.92783	.93341
45	.83214	.84310	.85277	.86131	.86907	.88255	.89396	.90380	.91211	.91937	.92570	.93131
50	.82977	.84076	.85042	.85902	.86676	.88030	.89174	.90160	.90997	.91723	.92358	.92919
51	.82929	.84028	.84994	.85855	.86629	.87984	.89128	.90115	.90952	.91679	.92316	.92877
52	.82881	.83980	.84946	.85808	.86582	.87937	.89083	.90069	.90906	.91634	.92274	.92835
53	.82833	.83932	.84898	.85760	.86535	.87890	.89037	.90024	.90860	.91590	.92231	.92793
54	.82784	.83883	.84859	.85712	.86488	.87843	.88991	.89978	.90814	.91546	.92189	.92751
55	.82736	.83834	.84802	.85664	.86441	.87796	.88945	.89933	.90768	.91502	.92145	.92707
56	.82689	.83787	.84756	.85618	.86395	.87750	.88900	.89887	.90724	.91459	.92102	.92666
57	.82642	.83740	.84709	.85571	.86348	.87704	.88855	.89842	.90681	.91416	.92059	.92625
58	.82594	.83693	.84662	.85521	.86302	.87659	.88810	.89797	.90638	.91373	.92019	.92583
59	.82547	.83646	.84615	.85477	.86256	.87614	.88795	.89752	.90595	.91330	.91975	.92541
60	.82500	.83595	.84568	.85430	.86208	.87569	.88720	.89707	.90549	.91287	.91933	.92499
61	.82453	.83552	.84520	.85382	.86162	.87523	.88674	.89662	.90504	.91242	.91890	.92455
62	.82405	.83504	.84473	.85335	.86115	.87476	.88628	.89617	.90460	.91198	.91847	.92412
63	.82357	.83457	.84426	.85288	.86069	.87430	.88582	.89571	.90416	.91154	.91803	.92369
64	.82310	.83409	.84379	.85241	.86022	.87384	.88536	.89525	.90372	.91110	.91759	.92326
65	.82262	.83362	.84334	.85193	.85976	.87337	.88490	.89479	.90328	.91066	.91715	.92283
66	.82214	.83315	.84286	.85145	.85928	.87291	.88443	.89433	.90284	.91023	.91670	.92241
67	.82167	.83268	.84237	.85096	.85880	.87245	.88395	.89387	.90239	.90978	.91625	.92198
68	.82119	.83221	.84189	.85048	.85832	.87198	.88348	.89342	.90194	.90934	.91581	.92155
69	.82071	.83173	.84141	.84999	.85784	.87151	.88301	.89297	.90149	.90890	.91537	.92112
70	.82023	.83124	.84092	.84951	.85736	.87105	.88254	.89252	.90104	.90847	.91493	.92062
75	.81780	.82878	.83851	.84710	.85496	.86864	.88018	.89018	.89872	.90617	.91270	.91849
80	.81530	.82631	.83603	.84467	.85248	.86622	.87776	.88781	.89639	.90385	.91046	.91622

One hundred parts (by weight) of Water
with

Heat	100 Alc.	90 Alc.	80 Alc.	70 Alc.	60 Alc.	50 Alc.	40 Alc.	30 Alc.	20 Alc.	10 Alc.
40°	.93827	.94295	.94802	.95328	.95879	.96434	.96967	.97472	.98033	.98795
45	.93621	.94096	.94605	.95143	.95705	.96280	.96840	.97384	.97980	.98774
50	.93419	.93897	.94414	.94958	.95534	.96126	.96708	.97284	.97920	.98745
55	.93208	.93696	.94213	.94767	.95357	.95966	.96575	.97181	.97847	.98702
60	.93002	.93493	.94018	.94579	.95181	.95804	.96437	.97074	.97771	.98654
65	.92794	.93285	.93822	.94388	.95000	.95635	.96288	.96959	.97688	.98594
70	.92580	.93076	.93616	.94193	.94813	.95469	.96143	.96836	.97596	.98527
75	.92364	.92865	.93413	.93989	.94623	.95292	.95987	.96708	.97495	.98454
80	.92142	.92646	.93201	.93785	.94431	.95111	.95826	.96568	.97385	.98367

Besides the specific gravities here given, the original tables contain several particulars deduced from the experiments, such as the quantity of real spirit in a given bulk of the mixtures, the actual condensation expressed in numbers,

and the like. Some of these chiefly concern the business of the exciseman, but with regard to the condensation, we shall extract the following results deduced from the same tables.

One hundred parts, in bulk, of the pure spirit, at the temperature of 60°, mixed

of water	parts	
with 25 diminish in bulk	2.31	being about $\frac{1.0}{5.41}$ of the whole before mixture
50	3.76	- - - - - $\frac{1.0}{4.60}$
75	4.82	- - - - - $\frac{1.0}{3.63}$
100	5.60	- - - - - $\frac{1.0}{3.57}$
125	6.15	- - - - - $\frac{1.0}{3.65}$
150	6.53	- - - - - $\frac{1.0}{3.82}$
175	6.76	- - - - - $\frac{1.0}{4.06}$
200	6.81	- - - - - $\frac{1.0}{4.40}$

Hence it appears that the greatest diminution in bulk, or concentration, in proportion to the quantity of ingredients, which takes place between alcohol and water, occurs when equal bulks of each are used, being more than a thirty-sixth of the whole; but the greatest possible diminution obtainable by any admixture of water, happens when two parts of water are added to one of alcohol, being 6.81 parts where 100 of alcohol are employed. This last is the highest term of actual diminution, as it is again less than 6.81 in 100, if still more water is added.

The following results are given by two eminent French chemists, who have paid great

attention to the subject, Brisson and Beaumé. The experiments of each are made with much less minuteness, and there is reason to believe with less accuracy than those of Blagden and Gilpin. Those of Brisson were only made for one temperature, that of 10° of Reaumur (equal to 54½° Fahrenheit, and the usual standard heat taken by the French philosophers for experiments of this kind). Those of Beaumé were taken at every fifth degree of Reaumur, (from 0. to about 100 Fahrenheit.) Beaumé's experiments form the basis of his graduated spirit hydrometer (*pèse liqueur*) which is still employed in France.

BRISSON'S TABLE.

(Heat 54½° Fahrenheit.)

(The standard Alcohol being .8293 and the mixtures made by weight.)

Alcohol	Water	Sp. Grav.	Alcohol	Water	Sp. Grav.
16 with 0.		.8293	8 with 8		.9427
15	1	.8527	7	9	.9519
14	2	.8674	6	10	.9598
13	3	.8815	5	11	.9674
12	4	.8947	4	12	.9733
11	5	.9075	3	13	.9791
10	6	.9199	2	14	.9852
9	7	.9317	1	15	.9919
			0	16	1.0000

* BEAUMÉ'S TABLE.

(Heat $54\frac{1}{2}^{\circ}$ Fahr. The standard alcohol .8276, and the mixtures made by weight ,

Alcohol	Water	Degrees of Beaumés Hydrometer	Corresponding Sp. Gravity
16. with 0.	0.	40	.8276
15	1	37	.8421
14	2	34	.8571
13	3	32	.8675
12	4	$29\frac{1}{2}$	.8807
11	5	27	.8944
10	6	25	.9057
9	7	23	.9172
8	8	21	.9290
7	9	$19\frac{1}{2}$	.9382
6	10	18	.9474
5	11	$16\frac{1}{2}$	.9569
4	12	15	.9666
3	13	14	.9730
2	14	13	.9796
1	15	12	.9863
0	16	10	1.0000

From the above table it appears that the author's spirit hydrometer, at the temperature of 10° Reaumur ($54\frac{1}{2}^{\circ}$ Fahr.) indicates 40 degrees for the pure spirit, which is what the author also calls *prodigieusement rectifié*,^g or spirit rectified by simple but repeated distillation, the first third, or fourth part, of the product only being taken. It is satisfactory to observe how very exactly this accords with Blagden's standard alcohol, which is procured in the same manner, and is stated to be at 55° , .82736 specific gravity, so that these two may be compared in all their gradations. In point of accuracy of instruments, however, they are by no means comparable, those of Blagden and Gilpin being extremely delicate, whereas the incompetency of the hydrometer with the varying point of immersion, to very great accuracy, is now fully admitted. The entire range in this instrument is 30 degrees, the zero or point for distilled water being marked for 10 degrees. See the article HYDROMETER.

To proceed to the chemical composition of Alcohol. The remarkable circumstance of the production of water without any smoke or perceptible vapour, from the burning of spirits, was early noticed by Juncker, Geoffroy, and Boerhaave; but the reason of this phenomenon has been explained, by performing the experiment in the more accurate methods, which are entirely due to modern chemistry; namely, by operating upon known quantities in given por-

tions of air, and examining both the products and residues of combustion. Several modes have been pursued in the analysis of this substance, for the process presents considerable difficulties. Lavoisier attempted to burn a quantity of it in a small lamp, confined in a jar of oxygen gas; but this is attended with no small degree of danger; for if the spirit has remained long enough in contact with the oxygen to be in part volatilized and mixed with it, the first application of fire to the spirit also kindles the whole air thus mixed, and causes as formidable an explosion as that occasioned by firing oxygen and hydrogen gasses. Even if the spirit be kindled as soon as introduced within the oxygen, if the combustion goes on rapidly, the heat thereby generated evaporates part of the spirit within the jar, which then explodes, as in the former case. Only very small quantities of spirit can be consumed in close vessels, unless air be furnished to it very gradually whilst burning, but with this precaution an experiment of sufficient magnitude may be performed.

Lavoisier^h employed for this purpose a large bell glass, holding from 700 to 800 cubic inches, and inverted over a mercurial trough. A small lamp, filled with a known weight of alcohol, was introduced under the glass, swimming on the surface of the mercury, and the wick was armed with a minute portion of phosphorus. The common air within the glass was sucked out by a syphon, till the mercury rose to a cer-

^g Hassenfratz, An. Chim. Tom. 33.^h Beaumé, Elem. de Pharmacie.^h Ency. Meth. Art. Alcool.

tain height, which was noted, and the wick being then kindled the spirit took fire. When the flame was weakened, a fresh supply of air was sent into the bell-glass from a reservoir of oxygen gas, through a syphon tube, and this was kept up with great precaution, till the quantity of carbonic acid generated was so great as to extinguish the flame. On examining the results, it was found that 93.5 grains of alcohol and 110.32 grains of oxygen had been expended in the combustion. The products were 93.8 grains of carbonic acid, and 106.2 grains of water, so that the quantity of water *exceeded by 12.7 grains the entire quantity of the alcohol*. From these data, and from previous experiments on the proportion of oxygen required to convert carbon into carbonic acid, and hydrogen into water, Lavoisier concluded the composition of the alcohol, on which he operated, to be as follows:

Carbon - - - - -	28.53
Hydrogen - - - - -	7.87
Water (already existing in the alcohol)	63.6
	100.00

Whatever doubts may be thrown on the entire accuracy of the numbers here given, two principal points are ascertained to be the leading objects of remark in the analysis of alcohol by combustion, namely, the production of carbonic acid, and the generation of a quantity of water, even more than that of the alcohol itself. In the latter circumstance, the combustion of alcohol agrees with that of hydrogen, in the former it differs.

The mere production of water was exhibited by Lavoisier in the following method. A spirit lamp, drawing air freely from the atmosphere, was set within a small chimney, which conducted the heated vapour into a spiral worm tube, kept cool by being surrounded with cold water, as in common distillation. The water produced by the burned alcohol was condensed in the warm tube, and being collected and accurately measured, was found to exceed the quantity of spirit consumed by about one sixteenth; sixteen ounces of spirit having generated about seventeen ounces of water. The carbonic acid produced at the same time, was not noted.

The experiments of Dr. Priestley also throw much light on the composition of alcohol. By taking the electric spark in this fluid, he obtained from it a considerable quantity of highly inflammable air.ⁱ But the most curious expe-

riments were made by passing the vapour of heated alcohol through tubes of earth or copper made red hot.^k When earthen tubes were used, the spirit was mostly converted into inflammable air, the tubes themselves remaining unaltered. But it was otherwise with the copper tubes, for, as the author observes, "the vapour of the spirit of wine had no sooner entered the hot copper tube, than I perfectly astonished at the rapid production of air. It resembled the blowing of a pair of bellows. But I had not used four ounces of the spirit of wine, before I very unexpectedly found that the tube was perforated in several places, and presently afterwards was so far destroyed, that in attempting to remove it from the fire, it actually fell in pieces. The inside was full of a black sooty matter resembling lamp-black."

Not only was much of this sooty matter detained by union with the copper, but a very large quantity escaped in the form of a black incombustible vapour, which presently filled all the vessels that were set to receive it, and could not even be condensed by passing through water. The copper, rendered black and friable by this process, the author terms *charcoal of copper*. The other metals that were tried did not answer so well as copper in decomposing the alcohol.

Dr. Priestley's valuable experiments were repeated by Dr. Van Marum, and the other associated chemists of the Teylerian Institution of Amsterdam. Wedgewood's porcelain tubes were employed, which were prevented from cracking on the sudden application of heat, by being first inclosed in iron tubes the length of the furnace. One extremity of the earthen tube united with the retort in which the alcohol was boiled, the other terminated in a metallic serpentine, or spiral tube, immersed in water, to receive and condense the vapours which might be generated. Copper wire was introduced within the earthen tube, and when made red hot, the vapour of the boiling spirit was sent through. The results of the different experiments were the same essentially with those of Dr. Priestley, that is, the alcohol was decomposed, and furnished much carbonaceous matter, which united with the copper, converting it to a friable carburet. Dr. Van Marum also found that a very large quantity of hydrogen gas was given out in the process, the more abundant in proportion to the intensity of heat in the tube. Three ounces of alcohol in one experiment, gave ten cubic feet of carburetted

ⁱ Experiments on Natural Philosophy, Vol. I. ^k Ditto Vol. III.

hydrogen gas, and 180 grains of charcoal, united with the copper; but the results of the other experiments differed as much in the proportion of this matter as that of the hydrogen.

These experiments, though highly curious, are too variable, and offer too complicated results, to throw much light on the actual proportion of the constituent parts of alcohol: for, on the one hand, the charcoal produced does not equal the quantity estimated to exist in spirit by Lavoisier's experiment; and on the other, the quantity of the hydrogen gas given out is so great, and its nature and proportion of dissolved carbon probably so various, in different parts of the process, that no calculation can be made from it with sufficient accuracy.

We can therefore at present only infer from all that has been done on the composition of alcohol, that it is composed of some hydrogen and much carbon, probably in intimate union with each other, also joined to a certain proportion of water, varying according to the specific gravity of the spirit, but which even in the most concentrated alcohol which we are able to produce by art, forms, perhaps, full half its weight, and appears to be a necessary constituent.

With the large proportion of carbon which alcohol also contains, it is not easy to explain why, during its combustion, contrary to the habitude of most other vegetable matter, every part capable of burning, is at once most completely oxygenized in the highest degree; and why, with so large a proportion of water of composition, it is found to be, when pure, so highly combustible.

The mutual action between alcohol and various saline substances, deserves notice.

The fixed alkalies, when caustic, are soluble in this spirit, as we have already mentioned, but the carbonated alkalies have no other action on it than to deprive it of its redundant water. When caustic alkali is digested with alcohol, in a short time the spirit becomes of a yellowish, and afterwards of a high red brown colour, as it takes up the alkali. This solution is the *Tincture of Tartar* of Van Helmont, now disused in medicine. The solution may be made either by adding the caustic alkali alone to the spirit, or by mixing two parts of slacked lime, and one of carbonated potash, with eight of alcohol,¹ and frequently shaking the mixture till the whole is dissolved. The strongest alcohol dissolves about 0.187 of its weight of dry caustic potash, when heated. The spirit however is decomposed, partially or entirely according to the time of digestion, by this mixture.

The hot alkaline solution deposits on cooling, though kept in a close vessel, many rhomboidal or spicular crystals, the nature of which was not at first well understood, but which are now fully proved to be the crystallized, or fully saturated carbonated potash. The source of the carbonic acid in this case, must be the alcohol, which therefore must have undergone decomposition. Pelletier^m kept a pound of alcohol in digestion with four ounces of caustic potash for two years, in a matras stopped at the mouth with parchment. At the end of this time no spirituous principle remained in the liquor, which was of a deep red, and had deposited a large quantity of crystals of potash fully saturated with carbonic acid.

If the alcohol is distilled off the recent mixture with caustic alkali, it rises extremely pure and dephlegmated, but at the same time it undergoes much loss in quantity of actual spirit, and if this be repeatedly abstracted by distillation, the spirit is lost, being converted partly into carbonic acid, and also into the acetous, both of which appear united with the alkali into the carbonat and acetite of potash. Lime decomposes the spirit by distillation as potash does, much water is separated, the spirituous is exchanged for a nauseous smell and taste, and the lime becomes carbonated. Lime water simply deposits its lime when mixed with pure alcohol, and the earth is in a caustic state.

Pure ammonia readily dissolves in alcohol, and the carbonated volatile alkali to a certain degree, especially when united by means of distillation. However, alcohol added to a saturated solution of carbonated ammonia in water, separates the greatest part of the salt in a confusedly crystalline mass called formerly *Offa Alba Helmontii*. (See AMMONIA).

The stronger acids act in a very remarkable degree upon alcohol, producing by the mixture that fragrant, light, inflammable liquid called ETHER; and also a quantity of carbonic, oxalic, and acetic acids, all arising from the mutual decomposition of the spirit and acid. We shall describe, under the article *Ether*, the various processes for obtaining it, and shall here only mention a few of the facts which throw light on the composition of ardent spirit.

Scheele observed, that when spirit of wine and sulphuric acid are distilled together, after the ethereous product is given out, a quantity of acetous acid rises by continuing the heat, which is mixed with the sulphureous acid gas.

But the nitric acid acts with more energy

¹ Meyer.

^m Mem. & Obs. de Chimie.

in decomposing alcohol. Bergman mentions that the residue left after distilling twenty-four parts of nitrous acid and eight of alcohol, if re-dissolved and crystallized, gives three parts of crystals of oxalic acid. The following experiment will shew the decomposition of spirit. On one pound of strong alcohol put into a long necked retort, and connected with the pneumatic apparatus, add four ounces of strong nitrous acid, with great caution, at repeated times, and apply a very gentle heat. Nitrous ether, nitrous gas, and carbonic acid are at first given out, which last may be absorbed by lime water, and rendered sensible. When no more gas is given out, add three ounces more of the nitrous acid to the residue, which, again distilled, gives the same products as at first. Then by slow evaporation of the liquor left in the retort, crystals of oxalic acid will be obtained. If the quantity of nitrous acid be considerable, or the boiling of the materials brisk, much acetous acid is also obtained, which is found mixed with the distilled nitrous ether.

Under the article *Acetous Acid*, the operation of the oxy-muriatic acid upon the residue of the distillation of nitrous ether, is also described, and the production of the acetous and oxalic acids.

The preparation of Howard's *fulminating MERCURY* also shews, in a striking manner, the generation of oxalic acid from alcohol, by the nitric acid, this singular compound being an oxalat of mercury, prepared by digesting alcohol with the nitrat of that metal.

The weaker acids, such as the oxalic, gallic, tartaric, and the like, when added to alcohol, are merely dissolved by the spirit, but do not appear to decompose it, except very imperfectly and with considerable difficulty. Many of them are crystallizable from the hot alcoholic solution by cooling, such as the gallic and oxalic acids. The latter requires $2\frac{1}{2}$ times its weight of alcohol in a cool temperature for solution, but only about $1\frac{1}{4}$ of boiling spirit.

The alkaline, earthy and metallic neutral salts, are very variously affected by alcohol. Some it dissolves copiously, others sparingly, and those on which it has little or no solvent power, it precipitates from their watery solution. The solubility of salts in alcohol is a subject of considerable interest to chemical analysis, and several series of experiments have been made, some of which we shall notice.

Macquerⁿ examined with great care the solubility of the sulphats, nitrats and muriats of

potash, soda, ammonia, lime, silver, copper, iron, and mercury. To prevent inaccuracy with regard to the variable quantity of water of crystallization, he dried them all in a heat sufficient to expel this water. The alcohol was the same in all, being of the specific gravity of .8437, at 54.5 Fahr. equal to .840° at 60°. The salts were put separately in a matras, half an ounce (French), or two hundred and eighty-eight grains of the alcohol, was poured on them, the vessel was corked and heated till the spirit began to boil, after which it was immediately filtered while hot, and first suffered to cool gradually, to ascertain whether the salt would deposit by crystallization, and next evaporated entirely and the total residue collected and weighed. A second comparative experiment was made on each, in which the spirit was burnt off, instead of being evaporated, that the appearance of the flame might be noticed.

The sulphats were all found absolutely or very nearly insoluble. It is remarkable that the dried sulphat of copper gave no green colour to the flame of the spirit, though when with its water of crystallization this colour is very apparent.

Of the nitrats, four grains of nitre were dissolved in the half ounce (or two hundred and eighty-eight grains) of alcohol, part of which crystallized on cooling. The flame of this solution was much larger, yellower and brighter than that of common alcohol.

Of the nitrated soda fifteen grains were dissolved. The flame was like the last, but more intense. Nitrated ammonia dissolved in very considerable quantity; one hundred and eight grains were found, after evaporation, of the spirit, which acquired somewhat of an ethereal smell by the boiling. The flame was white, luminous, and somewhat fuliginous.

The alcohol dissolved its own weight of nitrated lime, and the solution was thick like oil. None of the salt was deposited by cooling. The flame was large, red, and luminous, and the spirit burned with a crackling noise.

Eighty-four grains of nitrated silver were dissolved in the alcohol, which, as before, acquired something of the smell of ether. Nitrated mercury was scarcely soluble. Of nitrated copper forty-eight grains were dissolved; the flame beautifully bright and of a deep green.

Of the muriats, common salt was scarcely, if at all soluble in the spirit. Of muriated ammonia, twenty-four grains were dissolved by the half-ounce of spirit; of muriated lime, two

ⁿ Mem. Ac. Turin, tom. 3.

hundred and eighty-eight grains, or equal to the weight of the spirit, and the flame presented the same appearances with the nitrated lime. Luna cornea, or muriated silver, was entirely insoluble; of corrosive sublimate, two hundred and four grains were dissolved, much of which crystallized on cooling, and the flame was large, yellow, and decrepitating; of muriated iron, thirty-six grains, the flame white and brilliant, and towards the end, sparkling; of muriated copper, forty-eight grains, the flame beautifully green, accompanied with white and red sparks.

The above experiments appear to have been made with great care, and are therefore, to a considerable degree, accurate; but however, some unavoidable sources of error may be detected, which in some degree affect the results. In boiling the alcohol over the salt, some part of it must evaporate; in filtering the solution, a portion must remain in the pores of the filter; and in drying the salts, some of those with a metallic base would be liable to be, in some degree, decomposed. The experiments are notwithstanding valuable, and deserve notice.

Lavoisier made a series of experiments on the same subject, using alcohol, mixed with water, in eight different proportions. He found that the pure spirit did not dissolve either carbonated soda or sulphated soda, or sulphated magnesia, or common salt, or even muriated magnesia. When mixed with half its weight of water, it dissolved a considerable quantity of common salt, but sulphat of soda was not dissolved in any mixture in which the quantity of spirit exceeded that of water, without boiling, and on cooling the whole again crystallized.

Wenzel undertook a series of experiments on the same subject, of which the following is a part of the result.^o The quantity of spirit used in each trial was two hundred and forty grains; its specific gravity, however, is not mentioned, but probably it was somewhere be-

^o Gren. Syst. Hand.

tween .825 and .840°. The heat 180°, or about the boiling point of the spirit.

	Grains.
Nitrat of potash - - -	5
— soda - - -	23
— ammonia - - -	214
— lime - - -	288
— magnesia - - -	694
— alumine - - -	240
Muriat of potash - - -	5
— ammonia - - -	17
— lime - - -	288
— magnesia - - -	1313
Fluat of ammonia - - -	1
— alumine - - -	1
Borat of ammonia - - -	1
Tartrate of potash - - -	1
Cream of tartar - - -	7
Tartrate of ammonia - - -	7
— alumine - - -	7
Oxalat of alumine - - -	7
Acidulous oxalat of potash - - -	7

Lastly, we shall give the very accurate experiments of Mr. Kirwan^p on this subject, which is of so much importance in the difficult business of the chemical analysis of saline substances.

Mr. K. employed spirit of five different degrees of strength, namely, .817, or the most highly concentrated; .834 (or what, according to Mr. Gilpin's tables, would be produced by mixing one hundred grains of the purest spirit of simple distillation, viz. .825, with about 5 grains of water; .848 (equal to one hundred grains of the above spirit, with about 11 grains of water); .872 (equal to one hundred grains of the spirit, with about 27 of water); and .900, equal to one hundred of the spirit with about 59 grains of water. The temperature was never higher than 80°, the time of digestion about three days, and the salts were deprived of their water of crystallization.

^p On Mineral Waters.

100 grains of ALCOHOL at

	.900	.872	.848	.834	.817
Sulphat of soda - - - - -	0	0	0	0	0
magnesia - - - - -	1	1	0	0	0
Nitrat of potash - - - - -	2.76	1	0	0	0
soda - - - - -	10.5	6.		0.38	0
Muriat of potash - - - - -	4.62	1.66		0.38	0
soda - - - - -	5.8	3.67		0.5	
ammonia - - - - -	7.5	4.75		1.5	
magnesia, dried at 120°	21.25		23.75	36.25	50
barytes - - - - -	1.		.29	.185	.09
crystallized - - - - -	1.56		.43	.32	.06
Acetite of lime - - - - -	2.4		4.12	4.75	4.88

A subject of equal importance in chemical analysis, with the solubility of certain saline substances, is the precipitability of others from their aqueous solution on addition of alcohol. This takes place to a greater or less degree when spirit is added to a watery solution of any salt insoluble, or nearly so, in alcohol. Thus, by way of experiment, if some alcohol is added to a moderately strong solution of sulphated soda, in water, the spirit unites with the water, and precipitates the salt, which is seen to fall down immediately in the form of a white granular mass of irregular minute crystals.

There are some salts entirely separable from their water of solution by this method, which, when properly applied, is of great utility in analyses of water, particularly of mineral waters, where the foreign ingredients are generally composed of salts soluble and insoluble in alcohol. We are again indebted to Mr. Kirwan's^a accurate experiments for much information on this subject, directed particularly to ascertain the least proportions of the salt to the water, on which the spirit begins to exert its precipitating power, and the lowest specific gravity of the spirit requisite to produce this effect, as in all cases the precipitation takes place the soonest with the purest alcohol and the strongest saline solution. A gentle heat also much assists this separation.

The spirit must be at least equal in bulk to the saline solution, and sometimes twice or thrice the quantity is required.

The result of Mr. Kirwan's experiments were, that selenite may be completely precipitated from water that contains it in the proportion of $\frac{1}{1000}$ by any spirit whose specific gravity is below .850. The same precipitation takes place with regard to the alkaline sulphats of equal strength,

but these require a spirit of .817, and a longer time; so that sulphat of lime may be separated from the sulphats of potash and soda, simply by a properly managed addition of alcohol.

Alum must be in greater proportion than $\frac{1}{500}$ to be precipitated by spirit of .834, unless triple the volume of the solution be added, and heat be applied.

Sulphat of magnesia must be in greater proportion than $\frac{1}{240}$ to be immediately precipitated by alcohol of .834.

Alcohol digested for some days on PHOSPHORUS, dissolves a small quantity of it, sufficient to render the solution luminous in the dark, when spread on a warm surface (the face or hands for example) which evaporates the spirit. The quantity of phosphorus, though enough to shine in the dark, is too minute to do the least injury to the skin. The alcoholic solution dropped slowly into water, in a dark place, exhibits elegant waves of light, at the moment that the two liquids touch each other.

Sulphur is not acted on by alcohol by simple digestion either hot or cold, but the two may be made to unite by the medium of distillation. (See SULPHUR.)

The habitudes of alcohol with many of the most important vegetable substances, are highly interesting.

Most of the pure RESINS are soluble without difficulty in this fluid. The GUM-RESINS, however, are only partially soluble in strong alcohol, as it acts only on the truly resinous part; but a dilute spirit will hold the whole in perfect solution. If water be added to a spirituous solution of a pure resin, guaiacum for example, the water and spirit unite, and most of the resin is precipitated in the form of a flaky curd. This affords one method of obtaining these resins in

^a Min. Waters, p. 266.

great purity, in a solid or rather pulverulent form. A solution of a resin, or gum-resin, is called, particularly in pharmacy, a *Tincture*. If a saturated resinous tincture is slowly heated, the spirit evaporates, and leaves the resin at last, either as a soft tenacious paste, or, if further dried, concreted into a very hard brittle mass, retaining in a high degree, all the properties, sensible and medicinal, of the original substance. This is termed a *Resinous EXTRACT*, and the process is of use in concentrating into a small bulk the truly medicinal part of entire roots, or other gross parts of plants. The resin thus obtained from a tincture of jalap root is an example.

A few substances usually classed under the head of Resins, are however with great difficulty soluble in alcohol. Gum copal and amber are of this kind, but these partake rather more of the nature of fat oils.

Camphor dissolves with great facility in about four times its weight of alcohol of moderate strength. An addition of water separates the greater part of the camphor, the same as with the resinous solutions.

All the essential oils mix uniformly with alcohol, and are dissolved in it the more copiously in proportion to the strength of the spirit. This affords an easy and elegant method of giving flavour to the various spirits used for the table, and also of extracting the perfumed scents of flowers and plants for the toilet. See the articles *SPIRITS Distilled*, and *OIL Essential*.

Alcohol, resins, and essential oils, form the ingredients of a great variety of *VARNISHES*.

None of the fat oils, while in their original state, are soluble in this menstruum, which only extracts from them their colour and smell. But if altered, either by fire, so as to become *empyreumatic*, or by some of those processes which render them *concrete* and *drying*, or, if attenuated by repeated distillation, as in the case of the rectified *animal oil of Dippel*, or lastly, if previously united to an alkali into a *soap*, they become to a greater or less degree soluble in spirit.

Alcohol dissolves about one-third of its weight of good soap, if not overloaded with oil. The solution is perfectly limpid, and is of some use in the analysis of mineral waters, as a test for earthy salts, by which it is curdled.

The green colouring matter of the leaves and other parts of vegetables, is taken up by alcohol, according to the accurate observations of Mr. Sennebier. The green tincture is equally well prepared from the green pulp extracted from

these parts by water and digested in alcohol. The sun's light turns the colour of the tincture to a yellow. Water, acids, and alkalies, render it turbid.

Sugar dissolves in about three times its weight of alcohol of moderate strength, and as the spirit has scarcely any action on the mucilage with which sugar is mixed in the native sweet juices of vegetables, this liquid forms a useful medium for separating the pure saccharine part; too expensive indeed for the purposes of manufacture, but which may be applied with great advantage in analysis. For example, to separate the sugar from carrots, dry the root, reduce it to a coarse powder or paste, digest it in a heat brought slowly to boiling, with about its own weight of strong alcohol; strain the spirit, and separate the last portions by strong pressure, and slowly evaporate the spirituous solution to a small bulk, after which let it stand in a warm place till dry. The residue in most cases after such an analysis, is little else than the purely saccharine part. Most of it may be obtained crystallized, by a much slower and nearly spontaneous evaporation.

Not many animal substances are acted on by alcohol in any great degree. Those which it does dissolve are the animal resinous matters, such as musk, castor &c. spermaceti, adipocire, wax, and some of the altered oils; but in most cases the action of alcohol on animal substances is in a great measure similar to that on vegetable substances, resembling them in chemical nature.

In some cases alcohol acts only when dilute, and here it seems rather not to impede the action of the water with which it is mixed. So isinglass or other animal jelly will dissolve in common ardent spirit, and this solution spread upon thin cloth or silk, evaporates speedily, leaving a fine coating of the jelly. This is the basis of the well-known *Court* or *Sticking Plaster*. It generally happens that where alcohol does not dissolve, it coagulates, or separates from the watery solution. Thus it coagulates albumen from its natural solutions in the serum of blood, milk, and sometimes animal lymph. Milk curdled by ardent spirit, forms a well-known and agreeable preparation for the table.

If animal fibre or flesh is immersed in alcohol, its red colour, which depends on the blood remaining in the blood-vessels, is slowly extracted, and tinges the spirit; at the same time that the flesh itself becomes shrivelled, much hardened, greyish white, and absolutely incapable of putrefaction or further change.

Alcohol therefore is a most powerful anti-

septic, and it exerts this power upon every substance, animal or vegetable, capable of fermentation or spontaneous change.

The uses of alcohol in its various forms are very numerous and important. As the intoxicating basis of all vinous or spirituous liquors, it is only employed in the intermediate state of distilled spirits. In the arts it forms a most important ingredient in many varnishes; in pharmacy it is the liquid component of tinctures and other preparations; it preserves from corruption all the wet preparations of the anatomist; and to the chemist it is an invaluable agent, operating on a great number of substances for which no other proper solvent could be found, and at the same time altering their nature so little as to exhibit them nearly in their original state when expelled by evaporation. Many other less important uses might be mentioned, such as in filling thermometers, and another of great advantage in the nicer chemical operations, is that, as a combustible, it affords a gentle steady flame, unfouled by smoke or any vapour which can obscure the sight of the process which is going on in the vessel so heated.

Alcohol is seldom adulterated with any foreign matter. It should be neither acid nor alkaline, and the methods for ascertaining the degree of its dilution with water have been already mentioned.

It is of advantage for the purpose of the laboratory, to keep it of several degrees of strength for its different uses. Of these the specific gravity of .825 at 60° which is a very convenient standard for comparison, should be one; a higher degree of dephlegmation by means of potash, another; and two or three mixtures lower than the standard, such as .846 which is nearly the common rectified spirit of the shops, and one or two of inferior strength.

ALCOHOL Aceti, a term given by Wendenburg to his radical or concentrated vinegar. See **ACETOUS Acid**.

ALEMBIC, an article of chemical apparatus. See the *Appendix*.

ALEMBORTH Salt, a term nearly antiquated, employed to express the very soluble triple salt formed by uniting muriated ammonia to corrosive mercurial muriat. See **MERCURY**.

ALGAROTH Powder, is a white oxyd of antimony, prepared by dropping the liquid butter of antimony into water. It is by some used in medicine, as the basis of the emetic tartar. See **ANTIMONY**.

ALKALI.

ALKALINE EARTH. The class of alkalies

is amongst the most antient in chemical science, and one which has stood its ground through all the changes occasioned by modern discoveries, though with some modification.

The original application of the term *alkali* (which is of Arabian origin) was to express the acrid saline residue left in the ashes of the plant *kali*, after its combustion in open air. This was also very early known to the Greeks and Romans; by the latter termed, *lixivial*, which term is still retained, *lixivium*, or *ley*, meaning properly the soluble salt extracted out of vegetable ashes by the addition of water. From the circumstance of the ashes being the fixed or unvolatilized part of the plant, the rest having been dissipated by the combustion, the lixivial salt was also called *fixed alkali*, a term still in universal use. The proper fixed alkalies are of two kinds, the vegetable or *potash*, and the mineral or *soda*; the latter is found often native in immense quantities being the basis of rock salt, and is also the principal saline residue of many plants growing on the sea shore; and the former is contained in, and almost entirely procured from, the ashes of vegetables in general, not growing contiguous to the sea. Under the articles **POTASH** and **SODA**, and **CARBONAT** of *Potash* and *Soda*, these most important Salts are fully described.

Again, as the volatile ammoniacal salt procurable from most animal matter (also of great antiquity) was found to agree with the other alkalies in taste, and in many chemical properties, though not in fixity, this ammoniacal salt was also termed an alkali, but *volatile*, in opposition to the two former, which remain unaltered in very considerable heat, and are therefore, comparatively, *fixed*. The volatile alkali is described under the article **AMMONIA**.

Of late years, some of the earths (especially barytes and strontian, which were unknown to antiquity) having been found to possess alkaline properties in no ambiguous degree, these have been by some chemists absolutely associated with the alkalies; by others have received the term *alkaline earths*, to express this resemblance which in the two above mentioned almost amounts to identity of properties; but in the two others, lime and magnesia, the agreement is only partial.

As it is but of little consequence which arrangement be adopted, provided an uniformity be observed, we have throughout the present work restricted the term *alkali*, to the three antient salts of that name; the two *fixed*, potash and soda, and the *volatile*, ammonia. Under

the appellation *alkaline earth*, we include the following, Barytes, Strontian, Lime, and Magnesia.

We shall now enumerate the properties usually described as belonging to alkalies, distinguishing how far they are possessed by the three salts and the four earths above enumerated.

The taste of an alkali is acrid, burning, and nauseous. It acts with so much energy and rapidity on the tongue, as to destroy, if concentrated, the skin of the part which it touches, and hence its extreme causticity. The three alkalies possess this in the highest degree, being more rapidly soluble than the earths, and of the latter only barytes, strontian, and lime, exhibit this corrosive taste, magnesia being absolutely insipid.

All the alkalies, except ammonia, are without smell, or nearly so, a particular urinous odour however arises during the solution with heat, of the other alkalies and earths, magnesia excepted.

Ammonia (whose natural state when uncombined, is that of a gas) magnesia, and probably lime, are incapable of crystallization, the other alkalies and alkaline earths are crystallizable.

Only the volatile alkali has been decomposed. The others have often been suspected to be also compound, and with some probability, but they have hitherto eluded the attempts of chemists to decompose them.

Ammonia alone is volatilized by the application of any degree less than a red heat; when fully red, or at a heat about that of melting copper, the fixed alkalies begin to be dissipated in dense vapours, but the alkaline earths resist any but the extreme degree of heat which has ever been applied.

The alkalies are extremely soluble in water, barytes and strontian in considerable quantity, lime, sparingly; magnesia scarcely at all.

They possess the strongest affinity for acids of all other bodies, uniting with them generally to such a degree as to produce perfect neutralization, or such a state of union, that the characteristic properties of both acid and alkali are lost, and new ones acquired. Most of the combinations with acids are considerably soluble in water, and all crystallizable with more or less ease.

The comparative force of affinity for the individual acids possessed by the alkalies and the alkaline earths, is not uniformly the same, but generally one or two of the earths stand the highest in force. The affinity of them all for

acids is superior to that of the metallic oxyds, and hence they decompose metallic solutions.

They all have their peculiar alkaline properties highly modified and lessened, but not entirely taken away, by union with carbonic acid. Hence the states of *mild* and *caustic*, the former expressing union with this acid; the latter, the contrary; which obtains in all these substances, though in magnesia alone the difference is scarcely perceptible as it regards the sensible properties.

They all unite with sulphur, forming compounds soluble in water, of a peculiar foetid smell, tarnishing the white metals, called sulphurets or hydro-sulphurets, according to circumstances.

They all unite with the fixed oils and animal fats, either into a true soap, or into a saponaceous compound. The fixed alkalies unite more perfectly with the oils, and the alkaline are the only true soaps, being soluble in water. The earthy mixtures with oil are indeed strongly combined, but are insoluble in water. Barytes will combine directly with oils, as M. Vauquelin has found,^a and when heated with animal matter, will cause it to give out a large quantity of ammonia, and will reduce it to a kind of saponaceous soluble mass.

When in fusion in a red heat (from which of course the volatile alkali is excepted) they dissolve flint into that beautiful transparent compound called *glass*. This property of vitrification is the strongest in the alkalies, but has been found by M. Vauquelin to be very powerful in strontian and barytes.

With the exception of magnesia, they all powerfully corrode the soft parts of vegetables, and especially animals. Bulk for bulk, the fixed alkalies are by far the most powerful and active in this respect.

Lastly, they all produce certain changes on some vegetable colours, and this test is perhaps the most striking of all above enumerated, since it is possessed by all without exception, though with some variety. The blue colours of many plants are changed by them to green, of which the syrup or tincture of violets, affords a ready instance; many of the reds, such as that of logwood and litmus, are changed into violet; and the yellow of a great many plants, such as turmeric, rhubarb, or liquorice root, is changed to a brown, or dirty brick red.

The latter change seems to be confined to the alkalies when both are carbonated, so that

the change of turmeric-yellow into red will distinguish the presence of a carbonated alkali from that of an alkaline earth, held in solution by an excess of carbonic acid. But when pure or caustic, the change is the same in both. The power of all these substances over the vegetable colours is very great in proportion to the quantity used, and it should be remarked, that in this instance also, acids and alkalies, or alkaline earths, are in direct opposition to each other, the acid restoring the colour to its original state, after it has been changed by the alkali, and vice versa. Hence a single coloured vegetable may be made a very delicate test for both acids and alkalies; litmus, for example, previously reddened by acids, will be changed into purple by alkalies, and purpled litmus will detect an acid by becoming red.

It appears therefore that there is scarcely a single characteristic except the change of certain colours, that will apply equally to all the alkalies and alkaline earths, but yet the general resemblance is so great as to justify this classification. Magnesia alone has the least claim to the title of an alkaline earth, and yet its affinity to acids is strong, and its power of changing some of the vegetable colours is very considerable.

ALKALINE Air. The term given by the discoverer, Dr. Priestley, to the volatile alkali in its pure or gaseous form. See **AMMONIA**.

ALKANNET. *Oreanette*, Fr. A colouring root, cultivated in many parts of the south of Europe, and brought in small quantities from the Levant. The plant grows to about a foot in height. The root, which is the part used as a dye, is as big as the thumb, red without and white in its inner part. The outer red portion is alone used for colouring. It grows in abundance in Languedoc, in dry sandy soils. The root is dried in the sun, and undergoes no other preparation. When good it is somewhat elastic though dry, of a deep red without, and should stain the finger nail freely when rubbed upon it, wet or dry.

Alkannet root imparts its deep red colour very freely to spirit of wine, the essential and fixed oils, wax, fat, and any other unctuous substance, and hence it is of considerable use in making some of the coloured oils or varnishes. To give a red colour to wax, for example, melt it, and infuse small pieces of the root in it for a few minutes, till it has acquired the requisite colour.

ALLOY. *Alliage*, Fr. *Legiren*, *Metallversetzung*, Germ.

A mass formed by the mixture of any two or

more metallic bodies, in which the different constituent parts cannot be distinguished from each other by their external characters, is an alloy. In this definition no distinction is made between mere intimate mechanical mixtures, and proper chemical compounds, because we are not as yet possessed of sufficiently accurate experiments, to ascertain which species belong to the former, and which to the latter class. The mixed metals into which mercury enters, are called **Amalgams**, and will be treated of at large under the article **Mercury**, as they are possessed of a number of curious and peculiar properties: in their general characters however they resemble the other metallic compounds, and therefore the observations in this article are equally applicable to each.

It is much to be regretted that a subject of such great importance both practical and theoretical, should have been so little attended to by modern chemists. The experiments of Gellert, Homberg, and Kraaft, inaccurate as they were, still continue to be our principal authorities, corrected and enlarged indeed on some points by Lewis, Darcet, Marggraf, and Guyton. But of all modern chemists, Mr. Hatchett is the one to whom this branch of the science is the most indebted: by shewing the peculiar difficulties which attend the investigation of this interesting subject, he has introduced considerable scepticism with regard to what has already been done; and the removal of ancient error is the first step towards the establishment of modern truth.

Almost every metal that is met with in commerce, contains a small variable proportion of some other metal, and therefore, strictly speaking, they are all alloys; thus lead contains silver; tin, arsenic; copper, iron; but after the usual processes of refining are gone through, the quantity which each holds of any other metal is so small, that its properties are not perceptibly altered by such admixture. A metallic mass therefore is scarcely considered as an alloy except the characters of the prevalent metal are obviously modified; in the same manner as the oil of vitriol of the shops acts the part and bears the name of sulphuric acid, notwithstanding a minute portion of potash with which it is combined.

Alloys are prepared either by melting the ingredients separately and pouring them together when they are liquid; or by fusing them all down together in the same crucible. When the metals employed are of different degrees of fusibility, and especially when the one that is

the easiest fusible is also very inflammable, the first method is had recourse to; as when copper and zinc or copper and tin are to be combined; but the latter is practised in those cases where the materials are either nearly of the same degree of fusibility, or at least where the temperature required for melting the least fusible, is not sufficient to volatilize that which is the most so. In order to prevent oxydation, the crucible ought to be lined with charcoal, and a quantity of decrepitated salt should be strewed over the top of the ingredients, which melting at a very low red heat, will float on the surface of the metal, and thus exclude the contact of the air. By taking these precautions, a lower and longer continued heat may be advantageously substituted for a shorter and more violent one, the ingredients will be mingled more perfectly, and the loss and consequent inaccuracy when experimenting on the most inflammable metals, will in a great measure be avoided. As soon as the mass is liquefied, it will be of advantage to stir it repeatedly, to prevent the ingredients from separating according to their respective specific gravity, before they have had an opportunity of combining together; for this purpose a charred stick, or rod of baked clay, is to be preferred to one of iron, as this last would in many cases be acted upon by the melted metal, and spoil the process. The alloy should also be poured alternately from one red hot crucible into another, and back again, to insure the intimate mixture of the ingredients. These are by no means useless precautions, for where one of the metals is of considerably greater density than the other, it requires particular care to make the quality of the alloy equal throughout the whole of the mass. Schlutter relates,^a that twenty pounds weight of silver, containing about a 56th part of gold, was melted in a crucible, and poured into cold water to be granulated: samples from the top, middle, and bottom of the mass were then assayed, and were found all to differ in their proportions of gold. In like manner Mr. Hatchett observed that gold made standard, with the usual precautions, by silver, copper, lead, antimony, &c. and then cast into vertical bars, was by no means distributed equally, but that the top of each bar, (being composed of the portion of alloy which occupied the *bottom* of the crucible) was both purer and of greater specific gravity than the lower end of the bar.

It is a matter of considerable importance to ascertain whether alloys are mere mixtures or

proper chemical compounds: in most instances there seems to be little or no doubt of the latter being the case, and perhaps all the supposed examples of the contrary may be looked upon as instances of the supersaturation of one of the ingredients by the other.

The rule that is laid down in most chemical books for ascertaining whether a mass of metal is an alloy or a simple mixture, is to fuse it with as little heat as possible, and to keep it in this state till its component parts separate from each other, like oil from water, according to their respective gravities. Thus if nearly equal parts of gold and silver are melted hastily together, and granulated by pouring into cold water, although the particles of gold and silver cannot be distinguished from each other by their external characters, yet they may be easily made to separate by melting the mass at a very gentle heat, keeping it in fusion for a quarter of an hour more or less, and then allowing it to cool gradually; the crucible being now examined, will be found to contain the gold, alloyed with a small variable proportion of silver in a lump at the bottom, and the rest of the silver wholly free from gold, lying upon it.^c It seems however by no means to be a necessary consequence of this fact, that the mass in question was not a proper alloy: the strong affinity of cohesion that subsists between the particles both of gold and silver, the great difference between their specific gravities, and the temperature at which they become liquid: all these forces concurring together in the most favourable circumstances, may well overcome a considerable degree of chemical affinity. Still less can it be hence inferred that no proportions of gold and silver can form a proper alloy.

Another objection to the method just mentioned of distinguishing alloys from mixtures, is, that it is applicable only to a very few cases. When, for example, a mixture of copper and lead is to be subjected to this trial, as soon as the separation begins to take place, part of the lead will occupy the bottom of the crucible, while the rest still mixed with the copper, will float above it: in proportion as the process goes on, and the copper becomes purer, a greater heat will be required to keep it liquid; the lead will then begin to boil, and particles of this metal in vapour will be constantly thrown up into the copper, so as to prevent the complete parting of the two, even supposing that no chemical affinity whatever subsisted between them. With still more force will this objection apply

^a Ess. des Mines et des Metaux. p. 256.

^b Phil. Trans. for 1803. p. 119.

^c Lewis. Comm. Arts. p. 86.

to a mixture of iron with any other metal that is heavier and more fusible than itself.

The evidence of chemical affinity between metallic substances, is of the same kind as in other cases, consisting either of an entire change of properties, or in such modifications of them, as are obviously not intermediate between those of the constituent parts. These we shall proceed to mention, premising however that there are more doubts and difficulties on this subject, than in any other department of chemical science.

It is a striking proof of affinity between two metals, when one being applied in vapour to the surface of another, of much greater fixity, and at a high temperature, quits its gaseous form without any diminution of heat, and enters into intimate union with it. Thus if a small crucible containing gold, is inserted into a larger one, and some bismuth be scattered in the space between, and the apparatus be raised to a white heat in order to melt the gold, the bismuth at this high temperature will be for the most part reduced to vapour, yet upon examination, the gold will be found to have combined with part of it,^d thus shewing that the affinity between these two metals is so great as to overcome the opposition presented by the difference in their specific gravities, and the elastic state of the bismuth.

The remarkable difference between the fusibility of some alloys and that of their constituent ingredients, may be considered as another sign of real affinity. As far as experiments have been instituted on this subject, it appears that the point of liquefaction in almost all alloys is lower than would have been inferred from the mean fusibility of their elements. Thus a mixture of gold and iron will melt at nearly the same temperature that is required for the fusion of gold alone. In some cases the fusibility of the alloy is even greater than that of its most fusible ingredients: thus an alloy of tin, lead, and bismuth, will become fluid in boiling water, a heat not sufficient for the melting even of bismuth, the most fusible of the three.

Some metals appear capable of uniting with each other in any proportions, as gold and copper, lead and tin, lead and silver, &c.: others are said to combine only to saturation, as silver and iron, lead and iron;^e of this however there seems to be some doubt; while a few have been reckoned absolutely incapable of combination; thus quicksilver is supposed not

to unite with either iron, cobalt, or nickel. Something however in these three instances is to be attributed to the hardness of the metals, and to their requiring for their fusion, or even softening, a heat much greater, that will entirely volatilize quicksilver, so that the circumstances most favourable to combination cannot in these cases be brought about. Thus much however is certain, that if iron be previously combined with tin or zinc, the mixture will dissolve in mercury without difficulty, forming in the first instance a magnetic, and in the latter an unmagnetic triple alloy.^f

The durability of alloys is in most cases much less than might be supposed from that of their component parts; so generally indeed does this happen, that Macquer and Gellert are inclined to deny to those metallic mixtures that are ductile, the name of alloys. This however is clearly carrying the matter to an excess. Some very ductile metals are rendered perfectly brittle by the addition of a very minute proportion of even another ductile metal, as is strikingly the case with the alloy of lead and gold: half a grain of the former rendering an ounce of the latter extremely spongy and brittle.^g In many of the brittle alloys however a variation in the proportion of the ingredients will so greatly modify this quality, without materially affecting the others, as to render it probable that brittleness is rather a proof of supersaturation than of chemical union. Iron when combined with about a fifth of tin, forms a white alloy, whose fusibility, specific gravity, &c. clearly demonstrate a chemical union, yet the compound is very soft and ductile: but when the proportion of tin is rendered equal with that of the iron, the mass is perfectly brittle. So in like manner copper, with $\frac{1}{16}$ of tin forms a malleable alloy, but if the tin is increased to $\frac{1}{3}$ of the whole, the alloy is brittle.^h Even brass, which when made of eleven parts copper to one of zinc, is more malleable than copper itself, becomes brittle when the zinc forms $\frac{1}{3}$ of the mass.ⁱ

In determining the difference between metallic mixtures and alloys, great stress has been laid on the specific gravity, and wherever this has been found to differ from what by calculation ought to have been the result, the mixture has been considered as a proper alloy without any further enquiry. The ascertaining of specific gravity however, is in common cases attended with considerable difficulty, and when

^d Hatchett, Phil. Trans. for 1803. ^e Guyton, An. de Ch. xliii. 47. ^f Own Exper. ^g Hatchett, Phil. Trans for 1803. p. 70. ^h Journ. de Phys. xii. 320. ⁱ Ibid. p. 318.

the specific gravities of various metals and metallic mixtures are to be compared with each other, the sources of error are so multiplied, as to render it difficult even for the most skilful to avoid falling into error. In the first place, care must be taken that the alloy and the ingredients of which it is composed, are under similar circumstances of compression: copper and gold in the state of wire, are specifically heavier than the same metals that have simply been fused; if therefore we melt together equal weights of copper wire of the specific gravity 8.87 and laminated gold, specific gravity, 19.36 and find that the specific gravity of the button of alloy instead of being equal to 14.11 is considerably less than the mean of its component parts, we shall yet by no means be justified in inferring from this fact that chemical union has taken place. The specific gravity of copper slowly cooled, and not wire-drawn, is only 7.78 and that of gold in the same circumstances, is 19.25, and this being also the state of the alloy, its calculated specific gravity, instead of being 14.11, ought to be estimated only at 13.51. Much also depends on the nature of the mould in which the alloy is cast; the specific gravity of the same individual mass being always less when cast in sand, than in iron. Thus Mr. Hatchett^k found the specific gravity of gold, made standard by British copper, and cast in iron, to be 17.281, while the same, cast in sand, was only 16.994.

Another circumstance as yet unattended to, and which influences the specific gravity of metals, whether pure or mixed, has been ascertained by the accurate chemist above mentioned.^l It is this: if the mould is not placed horizontally, the lower part of the bar or ingot will have to sustain not only the weight of the atmosphere, but also that of the upper part of the bar: hence there will be a difference in gravity between the top and bottom of an ingot, which will vary according to its length, and the horizontal angle in which it was placed while casting. Nor is this difference so trifling as might at first be supposed: a bar weighing twelve ounces of standard gold, was cast in a vertical position, and on an accurate examination, the specific gravity of the top was 17.035, and that of the bottom was 17.364: nor was this in any degree owing to the unequal distribution of the copper, for the proportion of pure gold in both pieces was precisely the same.

If however these causes of error are properly attended to and obviated, there seems no

reason why a change of specific gravity may not in these, as in other cases, be looked upon as an evidence of chemical combination. The bulk of some metallic mixtures is greater, and of others less, than that of their component parts, but we are by no means in possession of a sufficient number of accurate experiments, to draw any general inferences from this variation.

In a few cases the colour of an alloy may be considered as indicative of chemical union, being by no means intermediate between that of its elements: of this kind is the golden colour of the alloy of copper and zinc, and the silver hue of arsenicated copper; but the general similarity of colour between the white metals and their alloys, confines the application of this external character to a very few instances.

The most important but the most difficult investigation respecting the mutual action of metals on each other, is the elective affinity which has been obscurely observed in a few cases, and doubtless by proper attention may be traced in many more. In all instances where this takes place, there can be no question whether the substance operated on is a proper alloy or a mere mixture, the discovery therefore of facts of this kind is of peculiar importance. An amalgam of bismuth, is in part decomposed by allowing a bar of lead to remain suspended in it, a portion of the lead is dissolved, and the remainder is studded with crystals of bismuth, gradually deposited in the same manner as a piece of zinc decomposes a solution of acetite of lead.^m

The above are the principal general circumstances that have been observed concerning the action of metals on each other, a subject that may demand the abilities and will recompense the attention of the greatest and most accurate chemists, and which unfortunately has hitherto received less elucidation from the superior knowledge and skill of modern philosophers than any other branch of chemical science.

ALUDEL. An article of chemical apparatus. (See the Appendix.)

ALUM. *Alaun*, Germ. *Alun*, Fr. *Στυπτηρία* Gr. *Alumen*. Lat.

This salt, improperly denominated Sulphat of Alumine, in the modern nomenclature, is by far the most important of all those with earthy bases: we shall therefore treat of it considerably at length.

Much uncertainty prevails respecting the knowledge which the ancients possessed of this substance. The *στυπτηρία* of Dioscorides,ⁿ and

^k Phil. Transf. for 1803. p. 118. ^l Ibid. p. 123. ^m Own Exper. ⁿ Dioscor. V. ch. 123.

Alumen of Pliny,^b appear to comprehend a variety of saline preparations, resembling each other only in their styptic taste. We may however with tolerable certainty refer the *σχισμ* or *trichitis*, to the native alum of modern mineralogists; while the *υγξα* or *liquidum*, appears to be similar to the present manufactured Levant alum. This last is described by the authors above mentioned, as of an uniform texture, limpid, milk-white (probably on the outside) and in great use for dyeing wool of bright colours: it is characterized by Pliny, as striking a black colour with pomegranate juice, whence we may infer that it contained a small proportion of sulphat of iron, as the commoner kinds of alum do at present. Of the particular method of manufacturing it, we are almost wholly unacquainted; Pliny merely mentioning that it was made from water and mud, or in other words, by lixiviation. The best was obtained from Egypt, and the island Melos; it was also prepared in Cyprus, Sardinia, and the Lipari islands.

In the middle ages, alum-works were established at Roccha in Syria,^c (formerly called Edeffa) whence the commercial name of Roch alum, at Foya Nova, near Smyrna, and in the vicinity of Constantinople. From these places the Genoese, and other commercial states of Italy, procured the alum with which they supplied the Western and Northern parts of Europe. About the middle of the fifteenth century this manufacture was introduced into Italy, and the establishments of La Tolfa, Viterbo, and Volaterra, soon acquired an importance which induced Pope Pius II. to prohibit the use of Oriental alum. Early in the sixteenth century the art of preparing this salt extended to Spain and Germany. The alum works of Whitby in England, were established in the reign of Elizabeth, by Sir Thomas Chaloner: and in the seventeenth century the manufacture of alum began to be undertaken in Sweden.

Alum was well known by the older chemists to contain an earth in combination with sulphuric acid: but from its being precipitable in a white pulpy mass by a carbonated alkali, and being again soluble with effervescence in an acid, the common opinion for a long time was that this earth was the calcareous, and therefore that there was a considerable analogy between alum and selenite. Geoffroy, Baron, Hellot, and Pott, in their interesting experiments on this salt, shewed that its earthy base

was contained in clay; and Marggraf in his two memoirs on this subject,^d made a still nearer approach to the knowledge of its constituent parts. He shewed that the precipitated earth of alum, when well washed, is resolvable in sulphuric acid, even after it has been calcined, but that this solution yields on evaporation only a saline magma, instead of crystals of alum: the same effect takes place if a native clay is used, instead of the earth of alum. This able chemist also proved that the addition of a little potash to the sulphat of alumine, communicated to it the property of depositing octahedral crystals of genuine alum: he seems however to have considered the alkali only to be of use in combining with and neutralizing a certain oily or greasy matter, which by adhering to the crystalline plates of the magma, prevented them from coalescing into hard and perfect crystals. The essay of Bergman,^e on the preparation of alum (published first in 1767) added considerably to our knowledge of the ingredients and chemical properties of this salt: it is here shewn that a small excess of acid is necessary to the constitution of alum, since, when this is taken away, its taste, solubility, and crystallizability are destroyed. The author also mentions in the same treatise, that those lixivia, which on account of their great excess of acid cannot by mere evaporation be made to deposit alum, may be brought to a crystallizable state by the addition of potash or ammonia, but not by means of soda or lime. He further observes, that vitriolated potash and alum combine into a triple salt; yet is by no means of opinion that *all* alum necessarily contains either potash or ammonia; on the contrary he recommends the acid uncrystallizable lixivium to be treated with clay, in order to neutralize their great excess of acid, and dispose them to deposit a larger quantity of crystals than could be procured from the addition of potash. This proposed improvement of the manufacture was introduced without success into some of the German establishments, and many of the chemists of that nation began to consider alum as a proper triple salt, in which the presence of potash or ammonia was absolutely necessary: Professor Hildebrand, and Klaproth, in particular, were decidedly of this opinion. It is to the accurate and indefatigable Vauquelin, however, that chemistry is indebted for the latest and most satisfactory experiments on this subject, which have scarcely left any thing further to be known relative to the composition of this salt.

^b Plinii, Hist. Nat. L. xxxv. § 52. ^c Bergman, Ess. v. i. p. 338. ^d Mem. de l'Acad. de Berlin, 1754. p. 31. ^e Berg. Ess. v. i.

He first dissolved in pure sulphuric acid some alumine equally pure, and then evaporated the solution repeatedly to dryness, in order to drive off the excess of acid: the dry pulverulent residue being then re-dissolved in water, was brought by evaporation to various states of specific gravity, for the purpose of crystallization; but notwithstanding every precaution, a flaky crystalline residue was all that could be procured. The solution which had thus constantly refused of itself to yield crystallized alum, began to deposit some immediately on the addition of a few drops of carbonated potash, and by accurately proportioning the alkali, the whole of the liquor, to the very last drop, was made to furnish by evaporation octahedral crystals of alum.

Another portion of the same pure aluminous sulphat was mixed with the same quantity of carbonated soda as had been employed of potash in the preceding experiment, but no crystals were deposited, even by evaporation. Nor were lime or barytes more efficacious. Hence it may be inferred that alum is by no means a pure sulphat of alumine, and that the use of potash in promoting its crystallization is not to saturate a supposed excess of acid. This was further demonstrated by substituting sulphat of potash and sulphat of ammonia for these alkalis in their pure or carbonated states, in which case, being already saturated with sulphuric acid, they could not possibly contribute to deprive the aluminous sulphat of a supposed excess of the same acid; yet, in this case as in the former, the uncrystallizable sulphat of alumine was made to deposit crystals of genuine alum. The same effect took place even when acidulous sulphat of potash was substituted to common sulphat of potash.

It had been observed by Bergman, and other chemists, that a solution of common alum, if boiled with clay or pure alumine, loses by degrees its acid taste, becomes supersaturated with earth, and is no longer soluble in water: in this state it was called alum saturated with its own earth. This fact also was examined into, and still further elucidated, by M. Vauquelin. He found that a long continued boiling was necessary to produce this effect, and that the earthy alum thus formed, retained the potash, or ammonia, which it possessed in its soluble state, since by dissolving it in dilute sulphuric acid, octahedral crystals of alum were deposited. He further shewed that the presence of potash or ammonia was absolutely necessary to render the

alum thus supersaturated, insoluble: for by boiling pure acid sulphat of alumine with an additional portion of earth, the acid became completely saturated, but no precipitation ensued: having then added a few drops of sulphated potash, a deposition took place shortly after, possessing all the properties of the above-mentioned saturated alum. Another curious fact ascertained on this occasion was, that when alum contains a larger proportion of potash than usual, the form of its crystals, instead of being octahedral, becomes cubical, without any other remarkable change of properties.

Hence it appears that there are several varieties of salts, composed wholly, or for the most part of sulphuric acid and alumine, clearly distinguishable from each other, though generally confounded together under the common and vague name alum.

1. The first is sulphat of alumine, being a saturated combination of alumine and sulphuric acid.

2. The second is acid sulphat of alumine, and differs from the preceding only in containing an excess of acid.

3. The third is acid sulphat of alumine with potash, crystallizing in octahedrons.

4. The fourth is acidulous sulphat of alumine with potash, crystallizing in cubes.

5. The fifth is sulphat of alumine with potash, or alum neutralized by its own earth, pulverulent, insipid, insoluble in water.

6. The sixth is acid sulphat of alumine with ammonia.

7. And the seventh is acid sulphat of alumine with potash and ammonia, or the common alum of the shops.

The analysis of alum, when it was supposed to consist only of sulphuric acid, alumine, and water of crystallization, was very simple. Bergman recommends to take a given weight of alum and calcine it in a full red heat, in order to drive off the water of crystallization, the amount of which is indicated by the loss of weight in this process. A fresh portion of salt is then to be dissolved in water, and decomposed by the addition of carbonated potash; the precipitate, when well washed and ignited, indicates the proportion of earth; and the quantity of sulphuric acid is either estimated from the known weight of water and alumine obtained in the previous processes, or may be calculated from the sulphat of potash resulting from the evaporation of the residual liquor, after the separation of the alumine. The imperfections

however of this method are too obvious to need pointing out; we shall therefore proceed to notice the mode made use of by Vauquelin.

He first reduces a small piece of alum to powder, and adds to it a solution of caustic potash, in sufficient quantity to decompose it entirely; if then upon gently heating it gives out an ammoniacal odour, as is generally the case, this shows the presence of sulphated ammonia. Having obtained this indication, he dissolves three hundred grains of the alum in distilled water, puts the liquor into a tubulated retort, and adds quick lime equal in weight to the salt: by making this mixture boil for about twenty minutes, the whole of the ammonia is expelled, and may be condensed by cold water in the receiver, or in a Woulfe's apparatus: this ammoniacal liquor being then carefully saturated with sulphuric acid, and crystallized, will show the quantity of sulphated ammonia. The residue in the retort being mixed with warm water, and filtered, a clear liquor is obtained, containing the sulphat of potash, with some selenite, which last being got rid of by boiling and evaporation, the remaining fluid will then deposit the sulphat of potash in a crystalline form. When the previous assay does not indicate the presence of ammonia, the alum is to be decomposed by caustic ammonia, the precipitate is to be well washed, and the liquors, being added together, are to be gently evaporated to dryness: the salt thus obtained, is heated in a crucible, till it ceases to exhale white vapours of ammoniacal sulphat, and the rest is sulphat of potash. The objections to which this process is liable are, first, that the oxyd of iron is not at all noticed; secondly, that the lime will in part decompose the sulphat of potash; and thirdly, that the alumine, when mixed with lime, cannot without a long process be again separated. The following is, perhaps, upon the whole, the most accurate way of analysing the salt in question.

1. Of 1200 grains of alum take 400, and make a saturated solution of it in distilled water; add to this, in a tubulated retort, 400 grains of quick lime; boil the mixture for a quarter of an hour or twenty minutes, and the water condensed in the receiver will contain the whole of the ammonia. Saturate this accurately with sulphuric acid, and evaporate the liquor to dryness, continuing the heat till nothing remains behind but perfectly dry sulphat of ammonia.

2. Having thus ascertained the ammoniacal salt, take another 400 grains of alum, and ignite

it in an open crucible for a quarter of an hour; the loss of weight which it thus undergoes indicates the quantity of water of crystallization and sulphat of ammonia, the only volatile ingredients that it contains; but the amount of the latter of these having been determined in the first process, that of the former is also found by simple subtraction.

3. Take, lastly, the remaining 400 grains, and dissolve them in water to saturation; to this add liquid ammonia, as long as it occasions any precipitate; warm the mixture, and let it stand for some hours in a jar for the earth to subside; decant off the supernatant fluid, and replace it by more ammonia; then transfer the whole into a flask, and heat it moderately; return it afterwards into the jar, and when it has stood some time, pour off the clear liquor; wash the precipitate repeatedly with warm water, and transfer it to a filter to dry. The precipitate contains the alumine and oxyd of iron, all the other ingredients of the alum remaining in solution. When the precipitate is moderately dry, boil it in a flask with caustic potash; the earth will be dissolved, and the oxyd of iron may be separated by the filter, and requires afterwards to be washed and ignited; the alumine is then to be separated from its diluted alkaline solution, by being boiled with muriat of ammonia, and when washed and ignited, remains pure. We now return to the ammoniacal solution, into which, when previously neutralized by nitric acid, nitrat of barytes is to be dropped as long as any precipitate takes place: the sulphat of barytes thus procured denotes the quantity of sulphuric acid in the alum. The residual liquor now holding the nitrats of potash and ammonia, is to be evaporated nearly to dryness, at which period, a sufficient quantity of sulphuric acid being added, a further application of heat will drive off the nitric acid and sulphat of ammonia, leaving behind the sulphat of potash. Thus we obtain the quantity of sulphat of potash; that of the sulphat of ammonia being known by the first process, and that of the whole salt being indicated by the sulphat of barytes.

We shall now proceed to notice the manufacture of this salt. The earliest author who treats on this subject is Agricola,^s and he gives us a singularly perspicuous and satisfactory account of the methods pursued in his time, (about 1530,) for extracting alum from its earthy, stony and pyritous ores. He remarks that the lixivium, besides alum, contains sulphat of iron, which may either be crystallized with

^s De re Metallica, p. 456.

the alum, and separated afterwards by hand, or the sulphat of iron may be destroyed by the addition of a proper quantity of urine. He also mentions that the earthy sediments in the various processes are not thrown away, but exposed for a time to the air, and then boiled with water and urine, by which management the ore may be made repeatedly to yield as much alum as it did at first. It is remarkable that he does not mention a word of the use of potash, nor is it very clear by whom, or at what period, the use of this alkali was introduced into the manufacture.

The simplest process by which alum is prepared is that in use at the Solfatara, near Naples. It has been described by the Abbé Mazeas,^h and Fougereux de Bondaroy.ⁱ

The Solfatara, called by the ancients Forum Vulcani, Campi leucogei, is a small plain on the top of a hill, covered with a white soil, in which are perceived numerous round holes or craters, from which sulphureous vapours are constantly ascending. The ground, even at the surface, is considerably warm, and at the depth of a very few inches is so hot as to be intolerable to the hand. It is celebrated by Pliny (Nat. Hist. lib. xxx. ch. 50.) for its sulphur, but the alum establishment is of a much later origin. The white clayey soil of this plain, being penetrated and entirely impregnated by sulphureous vapours, forms a rich ore of alum, as may be ascertained by its strong styptic taste when applied to the tongue. In order to extract the salt, a shed is erected, in the middle of which is placed a large oblong leaden cistern, let into the ground almost up to the brim, in order to receive a proper quantity of the subterranean heat: this cistern is surrounded by smaller cauldrons, let into the ground in the same manner. When all is prepared, the extraction of the alum begins by putting some of the aluminous earth into the cistern, and pouring water upon it; this mixture is carefully stirred, till the whole of the salt is dissolved; after which, the earth being removed, a fresh portion is put in, so as to bring the water almost to a state of saturation. The liquor is now removed into the smaller cauldrons, and the loss by evaporation is supplied by fresh liquor, till a pellicle begins to appear on the surface. It is then removed into tubs, where, as it cools, it deposits a large quantity of crystals of alum. The mother liquor is returned to the cistern, where it is mixed with earth as before. The crystals of alum are purified by a second solution and crystallization,

after which they are fit for the market. Hence it appears that the alum exists ready formed in the earth of the Solfatara, and that the whole of the manufacturing part is reduced merely to lixiviation and purification. This alum, from the careless method of preparing it, is considerably fouled by sulphat of iron, and is in consequence little known beyond the Neapolitan territories. The proportion of alum contained in the ore must of necessity be very various; a specimen, analysed by Bergman, yielded only eight per cent. whereas the Abbé Mazeas procured, by simple lixiviation, two pounds and a half of crystals from six pounds of the earth, or about forty-one per cent. It is observable that no addition of potash or ammonia is made in this manufacture, the alkali must therefore exist in the ore. As no analysis has been made of this alum, it is impossible to tell which alkali it contains.

The alum works of La Tolfa, near Civita Vecchia, in the Roman state, are among the oldest in Europe, and as the alum manufactured here is reckoned the purest of any, we shall give a detailed account of the process, as reported by the Abbé Mazeas and Fougereux de Bondaroy,^k to whom we have already been indebted for the preceding particulars.

The ore made use of at La Tolfa, is the ALAUNSTEIN of the Germans, which is procured about a mile off the place where it is manufactured. It is found in irregular strata, and deep, almost perpendicular, veins in the side of a hill; and when unmixed with other substances, is of a yellowish white colour, and so hard as to require blasting by gunpowder. Being broken into pieces of a moderate size, it is first of all roasted. The furnace made use of for this purpose is a cylindrical cavity in a mass of masonry, the greater part of which is occupied by a hemispherical dome, with a large round aperture in its top. The fuel, which is wood, is conveyed by a side door into the dome, and the alum ore is piled skilfully over the aperture, so as to form a smaller dome, whose diameter is equal to that of the aperture in the lower one. As soon as the fire is kindled, the smoke and flame penetrate through the interstices of the pieces of ore, and quickly heat the whole mass. For the first three or four hours, the smoke escapes in dense black volumes, but by degrees it acquires a whiter colour, the pieces of ore become of a light red or rose colour, and a faint smell of liver of sulphur becomes manifest. At the end of twelve or fourteen hours

^h Mem. de l'Acad. des Sciences, vol. v. p. 389.

ⁱ Ditto for 1765, p. 275.

^k Ditto for 1766, p. 1.

the fire is extinguished, and when the alum stones are grown cool, they are taken down, and again arranged in the same manner as before, only observing to place those pieces near the centre of the fire which were before at the sides, that the whole may be equally calcined. The second roasting continues nearly as long as the first, and the stones are considered to have been properly managed if they are of an uniform white colour, and considerably styptic when applied to the tongue.

The second process commences by piling the stones upon a smooth sloping floor, in long parallel ridges, between each of which is a trench filled with water; from this trench the beds are frequently sprinkled, in proportion as they become dry by the action of the sun and wind. After a few days the pieces of roasted ore begin to swell and crack, and fall to powder like quick lime when it is slacked, acquiring at the same time a light reddish colour; and at the end of forty days, more or less, this operation is completed. Its success is materially influenced by sunshiny weather, the hottest periods of the year producing the best alum, and in the largest proportions, while long-continued rains entirely exhaust and spoil the ore.

The next stage of the manufacture consists in dissolving the alum out of the ore, and disposing it to crystallize. For this purpose a leaden boiler is filled two-thirds with water, and portions of the decomposed ore are successively stirred in, till the vessel is nearly full: when the liquor begins to boil it is diligently stirred up from the bottom, that the whole of the alum may be dissolved, and the waste by evaporation, is supplied from time to time by the mother water of a preceding crystallization. At the end of about twenty-four hours the fire is extinguished, and the liquor is left at rest for the particles of earth to subside; as soon as this has taken place, a stop-cock, fixed in the side of the boiler, about one-third of its height from the bottom, is opened, and the clear solution is transferred along a wooden spout, into square wooden reservoirs, seven feet high by five wide, so constructed as to be readily taken to pieces; in these it remains about a fortnight, during which time the alum crystallizes in irregular masses upon the sides and bottom. The mother liquor is of a flesh colour and unctuous appearance, and still rich in alum, it is therefore transferred into shallow receptacles, where it deposits, after a time, both earth and

crystals; these latter are taken out and separated from the impurities by washing in the residual fluid. Finally, this fluid itself is let out into a deep reservoir, whence it is pumped, to be mixed with fresh water and earth in the leaden boiler, as already mentioned. The earth, after having been once lixiviated, is thrown away, although by simple boiling with sulphuric acid, it may be made to yield a considerable quantity of pure alum.

From the analysis which has been already given of the ore of La Tolfa, under the article Alaunstein, it appears to contain all the component parts of alum, but over-loaded with earth and intimately mixed with filix: the chief advantage in the process of roasting, to which it is subjected previous to lixiviation, is probably the cracking of the stony masses in all directions, so as to render them easily disintegrable by the action of water. No alkali is added in the manufacture; the whole therefore of that contained in the alum, must have preexisted in the ore. By the analysis of Vauquelin,¹ the alum of La Tolfa contains

49. sulphat of alumine,
7. sulphat of potash,
44. water.

100.

Hitherto we have noticed only those ores which afford alum without the addition of potash or ammonia: by far the greater part however of the European alum is prepared from the aluminous slate (ALAUNSCHIEFER), or the aluminous earth (ALAUNERDE), and as these minerals contain only the remote principles of this salt, a much more complicated process is required than where the alum exists ready formed in the ore.^m The only necessary ingredients in the pyrito-aluminous ores are clay and pyrites, or sulphuret of iron; in addition however to these, there is always a variable proportion of bitumen, lime, and magnesia.

It is well known that iron pyrites, by the combined action of air and moisture, is converted into sulphat of iron, in consequence of the oxydation of the metal and the acidification of the sulphur: we know also that this salt, by further exposure to the air, undergoes a partial decomposition; the iron becoming highly oxydated, is incapable of combining with so large a proportion of sulphuric acid as it was united with before, in consequence of which a portion

¹ An de Chim. vol. xxii.

^m Jars Voyages Metallurg. v. iii. p. 287. Bergman Ess. v. i. Journ. des Mines, No. 46.
An. de Chim. vol. xxix. p. 247.

of sulphuric acid is set at liberty, to combine with that substance in the ore with which it has the greatest affinity. This substance is the lime, sulphat of lime will therefore be produced; and when the whole of this earth is saturated, the magnesia will begin to combine with the acid: the only two remaining substances in the ore are alumine and silice, the latter of which being insoluble in sulphuric acid, the whole of what remains, after saturating the lime and magnesia, must combine with the alumine. The lime and magnesia are doubly hurtful, as they not only absorb the acid in preference to the alumine, but their sulphats remain in the mother liquor, and prevent the crystallization of a part of the alum. Hence it appears that if these alkaline earths exist in the ore in so great a proportion as to unite with the whole of the acid, no alum can be produced, and that the richest alum ore, *ceteris paribus*, is that which contains the least of them.

The first process in the manufacture of alum from the pyritous ores, is the acidification of the sulphur, and the formation of sulphat of alumine: to effect which the common practice is to roast the ore as soon as it is procured from the mine. Upon a hard floor of rock, or well rammed clay, is laid a bed of faggots and coal, which is covered all over to the thickness of two or three feet with pieces of ore: fire is now applied, and as the heat penetrates through the mass, fresh quantities of ore are added, till the pile attains the height of thirty or forty feet. In Sweden, where they lixiviate the same parcel of ore repeatedly, the pile is built up with alternate strata of fresh ore, and that which has already been used one, two, or three times. In two or three months the fire goes out of itself, and the ore, if properly roasted, will be of a brown colour, and astringent to the taste: a red colour indicates that the heat has been too great, and the produce of alum is considerably diminished. The most judicious method, however, of preparing the ore for lixiviation, is that practised at Flone, in the department of l'Ourte, in France. When procured from the mine, it is sorted, according to its degree of hardness, and laid lightly in heaps ten or twelve feet high, which are sedulously watered during dry weather, as a certain degree of moisture greatly hastens this part of the process. The spontaneous decomposition of the pyrites, which is thus brought about, is very slow, the hardest kinds of ore requiring from three to four years. When upon examination the mass appears sufficiently impregnated with salt, the contents

are made into a pile, with alternate strata of faggots, and by a very judicious and gentle roasting, the sulphat of iron is for the most part decomposed, and its acid, uniting with the alumine and the potash produced by the combustion of the wood, forms alum. After the ore has been prepared by one of the methods above mentioned, it is lixiviated. For this purpose large receptacles of wood, or masonry, furnished with a double bottom and stop-cock, are nearly filled with the ore; upon which water is poured in various proportions, according to the custom of the manufactory or the supposed richness of the materials. The most economical method is to let the water remain for twelve hours in the first reservoir, containing ore that has been already twice lixiviated; then to transfer it for an equal time to that which has been once lixiviated; and last of all to mix it for the same number of hours with fresh roasted ore; after which it is turned into a large vat, where the earthy sediment is for the most part deposited. The liquor is judged to be sufficiently strong if its specific gravity is one-eighth greater than that of pure water, or 1.25.

The boiling down succeeds to the lixiviation, and is always performed in leaden vessels, copper being for the most part too dear a material, and iron being attended with the inconvenience of decomposing the alum in a considerable degree. The object in boiling is two-fold, first to evaporate a part of the water, and thus induce the salt to crystallize, and secondly to decompose the sulphat of iron. The lixivium being mixed with the mother water of a former crystallization, is boiled for twenty-four or forty-eight hours, according to the concentration of the liquor; during which much selenite and oxyd of iron is deposited, forming a crust at the bottom of the pan, that requires to be removed from time to time.

In Saxony, where the proportion of mother water is large, and the lixivium is brought to a high degree of concentration, the boiling continues without interruption for a week. At the end of these respective periods, the specific gravity of the liquor is assayed by a leaden hydrometer, or by filling a bottle of known size with the liquor, and then ascertaining by the balance the comparative weight between it and water. This being done, an alkaline solution is added, and the first crystallization is brought about. In the Saxon manufactories, where the liquor is uncommonly concentrated, as soon as the evaporation is finished, the contents of the boiler are let out into a reservoir, where they

are strongly agitated for half an hour, during which time a certain proportion of soap-makers lees and putrified urine is added. At Saarbruck, the potash is added twelve hours before the boiling is finished. In the English works, when the liquor appears by the hydrometer to be sufficiently evaporated, the fire is withdrawn from the boiler, and a stream of impure alkaline lixivium, from kelp and soap-makers ashes, is let into the liquor already in the boiler; at the same time the cock of the boiler is turned, so as to allow the contents of it to flow into a reservoir, by which management the two liquors are speedily and effectually mixed. It remains in this reservoir for three hours, during which it deposits an earthy and ferruginous sediment, and becomes of a clearer colour; it is now transferred to another large vat, and has its specific gravity again taken, according to which a greater or less quantity of putrid urine is added, to lower it to the required standard; being then agitated briskly for a quarter of an hour it is left at rest, and in the course of five days the crystals are deposited on the sides of the vessel. In some French and Swedish manufactories, the liquor, after being boiled down, is merely agitated for some time, without adding any alkali, and then passed into the crystallizing tub. The rough alum, or of the first crystallization, is always contaminated by a small quantity of sulphat of iron, from which it is mostly freed by washing in cold water, the latter salt being far more soluble in this fluid than the former. When washed it is ready to be refined; for this purpose a few hundred weights of alum are put into a pan, with as much soft water as is just sufficient for its solution when boiling hot; after the solution is effected, some bullock's blood is added, for the purpose of clarification; and at the end of about six or eight hours, when the alum is held in solution by only a little more fluid than its own water of crystallization, the liquor is run into casks, where it concretes almost entirely in a single mass. After ten or twelve days, the residual liquor is poured out, and the salt being broken into pieces of about a hundred weight, is ready for sale.

It may appear remarkable, and contradictory to the experiments of Vauquelin, mentioned in the former part of this article, that in some of the alum works there should be no addition, either of potash or ammonia, to the lixivium obtained from the pyritical ores, and yet that the produce of alum should be such as to render

the manufacture a profitable concern. The proportion of alkali required however being no more than three or four per cent. so minute a quantity may well exist in the ore, without being detected by chemical analysis, not to mention that part of it would undoubtedly be furnished by the wood with which the ore is roasted, and that ammonia would be formed by the combustion both of the bitumen contained in the ore and of the coals with which in England at least the wood is mixed.

The only manufacture of alum which has been conducted throughout on strict chemical principles, is that established some years ago by Chaptal, at Javelle, near Paris, with which we shall terminate our account of the modes of preparing this important salt.

According to the modern way of preparing **SULPHURIC ACID**, the requisite proportions of sulphur and nitre being mixed together, are brought to combustion in a close chamber lined with lead: the sulphur is thus acidified and converted to vapour, which, by degrees, unites with the water with which the floor of the chamber is overspread, and forms a diluted sulphuric acid. A similar process was established by Chaptal,ⁿ only substituting dried clay for the water, the result of which was so favourable, that a large manufactory on the same plan was set on foot, which has continued in full activity for several years, producing alum only inferior to that of La Tolfa.

The chamber in which the combustion is carried on is 91 feet long, 48 feet wide, and 31 feet in height, to the pitch of the roof. The walls are of common masonry, lined with a moderately thick coating of white plaster: the floor is a pavement of bricks, set in a mortar composed of equal parts of baked and unbaked clay; and this first pavement is covered by a second, the bricks of which are placed so as to lie over the joints of the lower one, and are themselves firmly connected to each other by a cement, composed of equal parts of pitch, turpentine and wax, made boiling hot, and poured between the joints instead of mortar. The roof is of wood, and the beams are set at much less distances than common; they are also channelled with deep longitudinal grooves, for the purpose of receiving the planks that fill up the space between the beams, so that the whole of this great area of carpentry does not present a single nail. The chamber thus constructed, was covered on the sides and top with a layer of the cement just mentioned, applied as hot as possible,

so as to penetrate into all the pores of the wood and plaster; three more successive layers were then laid on, and the last was polished, so as to present an uniform even face. In order to prevent the wood-work of the cieling from warping, it was covered on the outside with a thick coating of cement, and a light roof of tiles was laid over the whole. By substituting this cement for a lining of lead, a vast saving was effected in the first expence; and it has been found by long experience to require fewer repairs than even lead itself.

The clay made use of is of the purest kind, such as pipe-clay, that it may contain neither lime nor magnesia, and as little as possible of iron. It is to be tempered with water, and made into balls, five or six inches in diameter: these being dried in the sun are afterwards calcined in a furnace: the first effect of the heat is to blacken them; but soon after they become red hot, the carbonaceous matter which causes the blackness is burnt out. Being withdrawn from the fire and cooled, they are broken down into small fragments, and spread over the floor of the chamber. In this state they are exposed to the vapour of sulphuric acid, from the combustion of sulphur and nitre, and in a few days the pieces are observed to crack and open, and to be penetrated with slender saline crystals. The earth being at length covered with efflorescences, it is removed from the chamber and exposed to the air, under shelter of a shed, that the acid may be compleatly oxygenated and become thoroughly united with the earth. It is now lixiviated, and the liquor contains in solution little else than acidulous sulphat of alumine: this being boiled down to the proper consistence, a solution of acid sulphat of potash (being the residuum in the pots of combustion, from which the sulphuric acid was produced in the chamber, and consisting of the alkaline base of the nitre, combined with some of the sulphuric acid) is poured in: and the liquor being then transferred into a large vat, perfect crystals of alum are deposited, which are afterwards refined in the usual manner.

The advantages of this process are numerous. It may be carried on wherever a proper supply of clay can be had. The space taken up by the works is much less extensive than what is required according to the common methods. The whole manufacture is performed in at most one third of the time usually necessary. A large quantity of fuel is saved; the extraneous salts in the mother water are fewer; an important

use is made of the residual sulphat of potash; and lastly, the alum itself is much purer than usual, and almost equally well adapted to fix the delicate dyes as that of La Tolfa, the commercial price of which is generally about double that of the English alum.

Common alum, in whatever way it is prepared, is a salt of a sweetish acidulous taste, and extremely astringent. Its perfect crystalline form is that of a regular octahedron, composed of two four-sided pyramids, joined base to base: when crystallized on a flat surface, however, it more usually exhibits only four-sided pyramids. It is not very soluble in cold water, but readily so in hot. At 144° Fah. Roman alum requires fourteen times its weight of water for solution; fresh crystallized alum, holding as much water of crystallization as possible, requires thirteen parts; and English alum requires fifteen parts;° but, at a boiling temperature, alum will dissolve in less than its own weight of water. In a dry atmosphere, this salt becomes slightly efflorescent; when exposed to a moderate heat it melts, foams, and, as the water of crystallization evaporates, becomes of an opaque white, forming a spongy mass called *burnt alum*. In this state it is still soluble in water, with the exception of a small earthy residue. By exposure to a full red heat, a small proportion of sulphuric acid is driven off, and the remainder is insoluble in water.

Alum is decomposable by being heated with carbonaceous matter, the result being sulphuret of potash with alumine, which possesses the property of spontaneously igniting when exposed to a moist air, (see PYROPHORUS.)

Alum is also in part decomposable by the alkalies and alkaline earths, which abstract a portion of its acid, and occasion a precipitate of alumine, combined with potash and a little sulphuric acid. A similar effect is produced by iron, zinc, copper, and a few other metals.

Alum is also decomposable by vegetable fibre, and both vegetable and animal colouring matter, which it will precipitate from their solutions in water, leaving this fluid wholly colourless.

The uses of alum are various and important. It is an article of the *Materia Medica*; it is a necessary ingredient in most kinds of pigments and lake-colours, and in the various processes of dying. All leather that is not tanned or dressed with oil is prepared for use by means of alum. It is used by candle-makers to harden their tallow and render it white; and an unauthorized

use is occasionally made of it by bakers in the preparation of the finest white bread.

ALUM, *Native*. Of this mineral there are two varieties.

Var. 1. Plume Alum, *Alumen Plumosum*, Werner. *Feder Alaun*, Germ. *Alun de Plume*, Fr.

The colour of this substance is yellowish or greyish white; it consists of slender irregular hair-shaped fibres, either single or accumulated, and slightly adherent to each other. It is usually opaque, but sometimes transparent, and then possesses a small degree of lustre. It excites on the tongue a sweetish acerb taste, like common alum.

It is found efflorescing on bituminous schistus at Göttwig, in Austria; on grey argillite in Carinthia; in clefts and caverns on Stromboli, the Solfatara, the grotto of San Germano, Miseno, and other places in Italy.

The native alum of Miseno has been analysed by Klaproth,² who found that one hundred parts yielded, by simple solution and crystallization, forty-seven of perfect alum, and twenty-nine more by the addition of a little potash, the remainder being sand, with a small quantity of selenite and a slight trace of oxyd of iron.

Var. 2. Mountain Butter. *Alumen Butyraceum*, Werner. *Bergbutter*, Germ.

This differs from the preceding variety in being of a darker colour, and forming clots or lumps on the surface of aluminous schistus. At first it is very soft, with a waxy lustre and unctuous feel, but by exposure to the air it becomes harder and somewhat crumbly. Its taste resembles that of var. 1.

It occurs in many places where aluminous schistus is plentiful, and in a state of decomposition, as at Muskaw, in Upper Lusatia. It has not yet been analysed, but probably differs from the preceding in containing a larger proportion of alumine and iron.

ALUM SLATE, see ALAUNSCHIEFER.

ALUMINE. *Alaunerde*; *Reine Thonerde*. G. This term has been adopted in modern nomenclature, to signify the earthy basis of alum, or pure clay. This earth is one of the most extensively diffused in nature, its properties (at least the most important of them) have been familiar to mankind from the earliest antiquity, and on every account it requires particular attention.

Alumine is nowhere found native in a state of purity, and it is a little remarkable that in all the natural clays, in which some of its characteristic properties are the most conspicuous, it

never forms even half the composition, and generally no more than a third or a fourth; and on the other hand, it is found nearly uncombined in the hardest gems, and the corundum; minerals in which its existence was for ages unsuspected, till the experiments of the illustrious Bergman, and where it exhibits properties widely different from those of clay. The term Alumine therefore is well chosen, both as it suggests the most important saline combination of this earth, and as it prevents those erroneous ideas of its properties which might attach to the antient term clay.

We shall refer to the article CLAY (meaning by this appellation the natural earthy compounds possessed of plasticity, and employed in the several manufactories of pottery, porcelain, bricks, &c.) the leading mineralogical and technical descriptions relating to this earth, and shall here only describe the chemical properties of pure alumine.

Alumine when pure, is white, and without taste or smell. The natural clays indeed, and the other earths that contain much alumine, have a peculiar earthy smell when breathed upon, which is a test of some use in mineralogy, but this appears to be owing to the combination of clay with the oxyd of iron, and certainly does not belong to pure alumine. This earth is incapable of artificial crystallization, nor is it like flint, found native in a state of absolute purity and crystallized. However, in one or two varieties of the corundum gems, alumine forms by far the greater part of their composition, and thus circumstanced, this earth is regularly crystallized and intensely hard. A peculiar difficulty lies in the way of ascertaining the true specific gravity of this earth, which we shall notice when we have mentioned the effect of heat and water: in the gems it is considerable, being from about 3.99 to 4.28.

Alumine, either as it exists in the natural clays or when prepared pure by art, till it has been exposed to a red heat, unites readily with water into a very tenacious unctuous-feeling mass, which differs from all other wetted earths in being so plastic that it may be turned on a wheel, or moulded into any form. On adding more water it becomes gradually and equally diffused, making the liquor uniformly milky, and remaining very long suspended before it subsides. It is not however in any degree soluble in this fluid. Plastic clay retains water in greater quantity, and for a longer time than any other earth; on drying, if heated very gradually, it

* Analyt. Ess. p. 266.

shrinks in every direction, and at last cracks into a number of pieces, and returns to its original state. When thus dried at a moderate heat, it is soft, greasy, brittle, and crumbly; when rubbed, it takes a good polish, and remains equally plastic as before, on the addition of fresh water. But if it is dried at a full red heat, it becomes extremely hard, so as to strike fire with steel, is harsh to the touch, and now no longer miscible with water into a plastic mass, nor does it absorb any sensible quantity of this fluid. Its original properties however are regained on solution in an acid, and precipitation by an alkali, or vice versa.

Alumine in many instances gives its characteristic properties with respect to union with water, to a very large proportion of any other earth with which it is mixed. In the natural clays as we have mentioned, it never forms quite half the mixture. The very pure aluminous earth of Schemnitz, according to Klaproth,^a contains only 45 per cent. of alumine, and in the best porcelain clays the alumine is seldom more than from 25 to 30.

The action of heat on moistened alumine is very striking. The first effect is to expel most of the large quantity of water which it has absorbed in becoming plastic. The greater portion of this fluid is expelled at a very low red heat, or at the point at which the earth assumes that entire alteration in its texture as to lose the power of again uniting with the water which it has lost. In consequence of this it shrinks in every dimension. But the loss of weight and diminution of bulk do not stop here, for they both continue (the former in a diminishing ratio, the latter tolerably uniformly) up to as intense a heat as has ever been produced in furnaces. Hence it is that clay by its *contraction* affords as certain an indication of increase of heat as all other bodies do by their *expansion*: not that this earth however, is incapable of expansion by heat; for, like every other substance in nature, alumine does indeed dilate when heated, and contract when cooled; but this is only observable when the heat applied is not more than the highest to which it has been exposed since its plastic state: above this point the contraction peculiar to this earth (produced either by an actual loss of water or a different arrangement of its component particles) begins again to operate, and the extreme limit of its shrinking has never yet been precisely determined. A late eminent scientific manufacturer, Mr. Wedgwood, very ingeniously applied this property of

clay to the construction of a thermometer for measuring the more intense degrees of heat, where the common instruments were inapplicable; but several circumstances appear to shew that, though a valuable instrument, it is not susceptible of that degree of accuracy, which has been often attributed to it. (See PYROMETER).

Several experiments on the contraction of pure alumine by heat are related by M. Theodore de Saussure,^b (the son of a most illustrious father) which bear such internal marks of accuracy as at least to require attention, if not to ensure conviction.

M. Saussure observes, that when alumine is precipitated from alum by ammonia or by carbonated ammonia, it is capable of existing in two forms, according to the manner in which the solution of alum was made; if no more water was used than necessary to dissolve this salt, the precipitated earth when dried at about 80° is a white, friable, light, very spongy earth, sticking to the tongue, which the author calls *spongy alumine*. But on the other hand, if the alum is dissolved in a very large quantity of water, the precipitate dried at the same moderate warmth, will be transparent, yellow, brittle, cracking in the heat of the hand, like rolls of sulphur, with a smooth conchoidal fracture, not appearing like an earth, not adhering to the tongue, and *not again miscible* with water. This the author terms *gelatinous alumine*. At the above temperature of about 80° both species contain an equal quantity of water, though the spongy occupies ten or twelve times the bulk of the gelatinous. But at a higher heat they differ much in the power of retaining water. The spongy alumine loses at a full red heat, rather less than is sufficient to melt silver, all the water which it had absorbed, amounting to 58 per cent; so that 100 parts dried at 80° are hereby reduced to 42, and lose no further weight by the highest intensity of heat that can be given. But the gelatinous alumine dried at 80° is said by M. Saussure to lose only 43 per cent. of its weight at a silver-melting heat, 48½ at a heat of 130 of Wedgwood (or sufficient to melt cast-iron) and appears never at any higher heat to alter further in its weight.

The author gives in the following table the progress of the loss of weight (which it must be observed he only attributes to the volatilization of water) experienced by 100 parts of gelatinous alumine in powder, first dried at about 80° Fahr. and afterwards exposed to different tem-

^a Analyt. Essays.

^b Journ. de Phy. Tom. 52.

peratures, and accurately weighed after each experiment.

One hundred parts of the above alumine,

<i>Fabr.</i>		<i>Water.</i>
at 144	lose	12.2
257	—	19.
369	—	23.7
482	—	27.2
<i>Wedgewood.</i>		
13	—	42.3
29	—	45
85	—	46
106	—	47.5
133	—	48.25
170	—	48.25

On this table the author makes the very sensible remark that the contraction of clay (in the higher heats at least) cannot be exclusively owing to the loss of water, or to any loss sensible to the balance, since the diminution in weight from the thirteenth degree of Wedgewood to the highest intensity of heat is very trifling, whereas the contraction in the bulk of the clay, within these terms, is more than a fourth of its bulk.

Pure alumine is infusible in any heat that furnaces can procure, if not in contact with an alkali, or with any other earth which may operate as a flux. However, when exposed to oxygen gas from the blow-pipe, supported on a piece of charcoal, both Ehrman and Lavoisier found it converted into a milk white globule, imperfectly fused, and intensely hard, so as to scratch glass nearly as the diamond. Some doubt however arises, whether the alumine might not still contain a minute portion of potash, as it was prepared by precipitation from alum; the difficulty of procuring perfectly pure alumine in this method being very great, as we shall presently mention. Besides, as all charcoal contains some alkali, this might have assisted in the fusion, so that it is still doubtful whether pure alumine be capable of melting without addition, by any known heat. The other earths promote the fusibility of alumine when mixed with it. Gerhard found this earth fusible in a chalk crucible, but not in one of clay; Klaproth found lime to melt in a clay crucible, and not in one of chalk; but it is certain that alumine is one of the most refractory in the fire of all bodies in nature, and hence its use in its natural clayey mixtures in forming crucibles, furnaces, and vessels for resisting fire, and containing other bodies to be exposed to heat.

Fused with alkalies it does not run into a clear glass like the other earths, but forms an opaque, puffy, white, semivitreous, pasty enamel. So Klaproth found the corundum, in which the alumine is about 84 per cent. fuse with its own weight of carbonated soda in an intense heat, into an opalescent, greenish white hard glass. (For further particulars on the vitrification of earthy mixtures see the article GLASS.)

Alumine is soluble in most of the acids, with more or less facility, and *without effervescence*, unless newly precipitated from a solution, and still retaining a portion of carbonated alkali, which it does with considerable force.

For a complete solution, the assistance of heat is generally required, unless it be effected by double decomposition, as where acetited alumine is formed by adding acetited lead to alum. This earth is much more soluble when in its plastic state than after it has been heated, and most of all, immediately after precipitation from its solution, either in an alkali or an acid. The particular salts are described under the article *Alum*, and the respective acids.

Alumine dissolves with ease in the pure fixed alkalies, and even in ammonia if newly precipitated. If alumine in this fine state of division be put into three or four times its weight of a solution of potash, and heat applied, it dissolves like wax in oil, and by slow evaporation dries into rhomboidal pieces. Even the hardest aluminous stones, such as the CORUNDUM, yield to fusion with alkali with particular management. This solution lets fall the alumine when saturated with any acid, an excess of which redissolves the precipitate. Muriated ammonia also separates the earth from the alkaline solution by complicated affinity, the potash uniting with the muriatic acid, and the ammonia thus expelled determining the precipitation of the alumine, which when properly edulcorated and dried is now perfectly pure.^c

The affinity which the earths exercise for each other is a subject of the highest importance in chemical experiment, as it affects the result of the analysis of almost every mineral which has been hitherto examined; and late observations have thrown so much light on this question as (on some accounts unfortunately) to render unsatisfactory the labours of many eminent and excellent chemists, whose names have long carried with them the highest authority. We shall therefore compare the characteristic properties, and give the proofs of affinity of alumine with each of the other earths separately,

to assist the reader in the arduous task of chemical analysis.

In many circumstances alumine resembles filex so strongly as to have been frequently mistaken for it: in hardness, the aluminous gems surpass even that of rock crystal; both earths are soluble in fixed alkali, precipitable thence by an acid, resolvable in a slight excess of acid; and when in strong aggregation, the aluminous earth resists the solvent power of acids as completely as the siliceous. The most conspicuous difference between them as they occur in analysis is the following. Silix when redissolved by excess of acid (the muriatic for example) after being first precipitated by it from its alkaline solution, is entirely again separated by the application of heat, and by evaporation nearly to dryness, and then the earth remains insoluble on any future application of acid. Alumine, on the other hand, though the solution has been evaporated to dryness (if not otherwise decomposed by heat), remains again soluble on affusing fresh acid, and thus may be completely separated from the filex. To illustrate this, take two portions of a solution of filex in potash, the one concentrated, the other largely diluted; add to each an acid more than sufficient to saturate the alkali; in the former solution, much of the earth will be visibly precipitated, and again redissolved in the excess of acid; in the latter, because dilute, the same change will take place, but no turbidness will be visible. Then evaporate the solutions nearly to dryness, and a puffy coagulum will be formed in both cases, which is the filex, now no longer soluble, and is left in a state of purity, after due washing, in the form of a fine crystalline sand.

Perform the same process to alumine dissolved in potash, and after evaporation of the muriatic acid, pour on the earth some dilute sulphuric acid, boil for a short time, and a sulphate of alumine will be formed, which, on the addition of a little potash, or sulphate of potash, or acetate of potash, or any other salt containing this alkali, will give numerous crystals, which may easily be recognised for alum.

In another method the two earths may often be conveniently distinguished. Silix fused with as little as half its weight of dry carbonated soda, either in a crucible or before the blow-pipe, effervesces strongly, and at last forms a perfect transparent glass.

Alumine on the contrary does not froth, unites with the alkali with greater difficulty, and forms only an opaque, half-fused, whitish enamel.

By the above methods these two earths may be distinguished; the following facts shew their affinity, and will serve to warn the analytical chemist of the occasional difficulty of complete separation of the two. Klaproth found on analysing the Bengal corundum, that proceeding in the usual method of fusing with potash, dissolving the mass in muriatic acid, and evaporation, the filex was so strongly united with the large proportion of alumine as not to be precipitated in a gelatinous form by evaporation of the muriatic solution, as filex generally is, but remained in union with it till the alumine was prepared by solution in sulphuric acid and evaporation, for yielding alum in crystals. The filex then at last was separated, and assumed the gelatinous consistence peculiar to it under such a precipitation, and Klaproth further observed the coagulated filex in a short time to break into several separate unconnected figures in the shape of longish pyramids. When silicified potash is mixed with aluminized potash, the union contracted between the two earths is so great as for a time equally to resist entire separation by the common re-agents, as the same excellent chemist has also remarked.^a

When once coagulated to a jelly, if diluted with water and heated, the filex appears in purity as a white incohesive granular powder.

Mr. Chenevix^b also brings as a proof of the affinity of filex and alumine, that when fusing the mixture with potash, if the filex much predominates, a light flocculent siliceous earth appears, which is insoluble in muriatic acid; but if alumine much prevails, no such precipitate is found.

Magnesia is found to exercise even a greater affinity for alumine than filex, and hence it has long been a difficult problem in analysis to find a simple method of entirely separating them. We owe to Mr. Chenevix some very curious facts on this subject, introduced in his analysis of some of the magnesian earths, and first published in the volume of *Annales de Chimie* above quoted. Magnesia, when unaccompanied by any other earth, and dissolved in an acid, is well known to be only partially precipitated by ammonia, however in excess, the remaining liquor being a soluble ammoniaco-magnesian salt: but if both alumine and magnesia are dissolved in the same acid, the first effect of ammonia is to precipitate entirely the alumine, and in intimate combination with it, a larger portion of magnesia than the ammonia would separate in the former case; and it is only till

^a Klaproth, *An. Essays*, p. 68.

^b *An. Chim.* tom. 28. p. 203.

the alumine has carried down with it what may be considered as its saturating dose of magnesia, that a further addition of ammonia begins to form the ammoniaco-magnesian salt, if any magnesia still remains in the solution. The like takes place when the precipitant is an alkaline carbonat fully saturated with carbonic acid. Magnesia when alone, is first precipitated by it and then redissolved by the carbonic acid; but when in the same solution with alumine, both earths are entirely precipitated, and the magnesia is not again dissolved except it is in greater quantity than to satisfy the affinity of alumine.

On the other hand, alumine, when alone, is entirely precipitated from its acid solutions by caustic potash or soda, and again re-soluble by an excess of these alkalies; but if accompanied with magnesia, the power of resolubility is lost, except with regard to that portion of the alumine which exceeds the saturating affinity of magnesia.

Mr. Chenevix gives three modes of separating these two earths; first, by the malic acid, which, with magnesia, forms a deliquescent salt, and with alumine, one almost insoluble, so that alcohol will dissolve out only the malat of magnesia. This acid when native is preserved with difficulty, as it is not crystallizable, and mingled with a mucilage very apt to alter in keeping; but it is formed immediately by oxygenized muriatic acid and sugar, and though not unmixed in this method, the muriatic or acetous acids which remain in the solution, will, if properly managed, hardly touch the alumine. A second method of separating alumine and magnesia, is by sulphuretted hydrogen gas, which also forms a soluble hydro-sulphuret of magnesia, and does not touch the alumine: a third mode is by the prussic acid, which in like manner takes the magnesia, and leaves the other; both these reagents may be added in combination, that is, as an alkaline sulphuret, or prussiat. The malic acid is in one respect a preferable test to the two others, where there is iron in the mixed aluminous and magnesian solution; the malat of iron being very soluble, but the prussiat and hydro-sulphuret scarcely at all, so that with the malic acid the alumine is left uncombined by the first operation.

M. Vauquelin makes a similar observation to the above in a subsequent paper, on analysis^c in general; and remarks that in a mixed acid solution of alumine, lime, and magnesia, the addition of pure ammonia to separate the alumine singly is liable to error, owing to the

affinity above-mentioned, which determines the precipitation of magnesia (and lime also) along with the alumine: but if every thing is first precipitated by a carbonated alkali, the magnesia and lime will become carbonated in preference to any union with alumine; which last may afterwards be alone dissolved by caustic potash.

To separate alumine from magnesia, and also from lime and barytes, Bergman in his valuable memoir on the earth of gems recommends, after separating the silice in the way before described, to digest the mixed earths for an hour in six parts of cold acetous acid, which, he says, will not touch the alumine, but will dissolve the other earths. This is true to a considerable extent, but not perfectly accurate.

Klaproth separates these earths, when only these are present, by dissolving each in sulphuric acid, adding sufficient potash to convert the sulphat of alumine into alum, evaporating to dryness, and strongly igniting them for half an hour, and afterwards adding water: the sulphat of magnesia alone will now be soluble, and the alum only on the addition of fresh acid.

Lime shews also a certain degree of affinity for alumine, though not so powerful as magnesia. It is generally known to be a test of lime not to be precipitable from its acid solutions by ammonia; but Vauquelin has observed that this does not entirely hold true when lime and alumine are united in the same solution, part of the lime being then precipitable by ammonia, owing to the mutual affinity of these two earths. Mr. Chenevix also remarks, that when lime and alumine are boiled with potash, more of the lime is dissolved than the mere water of the liquid would take up singly; and as the alkali has no solitary action on lime, its solution in this case is a proof of its affinity with alumine.

Therefore the method usually adopted in analysis, of separating lime from the other earths (namely, after the silice is got rid of, first to precipitate the other earths and the iron from the acid solution by ammonia, with a view of leaving the lime in the liquid,) is not entirely accurate, since some of the lime will accompany the precipitate; so that it is a surer way to precipitate the whole by a carbonated alkali, after which the alumine may be taken out by potash which will not touch the lime now carbonated.

Barytes and strontian also shew an affinity for alumine. M. Vauquelin^d boiled together in water a mixture of strontian and pure alumine, newly prepared and still moist. Part was dis-

^c An. Ch. tom. 30.

^d An. Chim. tom. 29.

solved, but much left untouched. The solution would not crystallize by cooling as it does commonly, though much more strontian was used than requisite to saturate the water; and the solution saturated with muriatic acid gave a flocculent precipitate of alumine. On the other hand the undissolved mass was an intimate mixture of the two earths. Thus therefore alumine renders a large portion of strontian insoluble in water, and is itself partly dissolved in water by help of that small portion of strontian which preserves its property of solubility. Probably if the proportion of the two earths was exactly taken, according to their mutual affinity, none of the strontian would be dissolved.

Barytes was found to act precisely in the same method as strontian in this respect; and the smaller the proportion of the barytes, the less is the quantity of alumine dissolved. Besides, if hot saturated barytic-water be added to liquid muriated alumine, the mixed earth is precipitated, and again redissolved entirely by an excess of the barytes—a very striking resemblance to the action of alkali.

No very decisive affinity is shewn in analysis between alumine and oxyd of iron, though it is sometimes attended with some trouble to separate them completely. This is generally done by potash, which dissolves the alumine and leaves the iron; or if the earth still retains a portion of the metallic oxyd, recourse may be had to prussiat of potash, the two being first dissolved in an acid.

From all that has been said on the affinities of alumine, it may be imagined how difficult it is to procure this earth absolutely in a state of purity.

Pure alumine may be prepared either by precipitation from alum, or from the finer clays or aluminous earths. Each method has some particular advantages, but in each some precautions must be taken to ensure its efficacy.

In alum, the only earth is that which is intended to be obtained, which is a considerable advantage, but the affinity of this earth, both for sulphuric acid and for potash, is at least as great as that which it shews for the other earths, and accurate experiments have shewn that a single precipitation from alum can scarcely ever be depended on to obtain the earth absolutely pure. Ammonia, either pure or carbonated, is a better precipitant than potash, as the volatile alkali is completely driven off by heat. Berthollet found,* however, that alumine precipitated from alum, even by pure ammonia, and

welledulcorated, still contained a small portion of sulphuric acid, as was proved by affording a sulphuret when strongly heated with combustible matter. He therefore recommends, that the first precipitate from alum, by ammonia, be redissolved in nitric acid, purified from sulphuric acid by nitrated barytes, and again precipitated by the same alkali; and, after dueedulcoration, dried in a heat sufficient to expel the ammonia, whereby the earth is now obtained pure.

Lampadius† gives the following method, which is perhaps the best that can be adopted for a single precipitation. Dissolve two ounces of alum in thirty-two ounces of warm water, add a small quantity of prussiat of potash, and let it stand for a day to separate the iron, (a very proper precaution with most kinds of alum); then add sufficient pure ammonia to precipitate the greater part of the earth, but not the whole, by about a fifth or sixth, by which means the sulphat of potash remains in the mother liquor; after which, dry in a moderate heat to expel the water and ammonia that adhere, and the earth will in general be very pure.

A more economical mode, though by double precipitation, is the following, which, if carefully followed, will answer very well. Dissolve the alum, as in the last process, and separate the iron in the same way. Then precipitate the earth by carbonated potash,edulcorate well, and when the precipitate has dried a little into a cohesive mass, the filtration may be assisted by pressing gently in a fine cloth; then redissolve it, before it is quite dry, in muriatic or nitric acid; purify by nitrated or muriated barytes, from sulphuric acid, adding no more of the barytic solution than is barely necessary; and again precipitate the filtered aluminous solution by carbonated or pure ammonia; after which, wash and dry as before.

Alumine may be also obtained pure from its solution in potash, by adding muriated ammonia, as recommended by Mr. Chenevix, or simply by any acid of which the last portions may be entirely expelled by heat, if any should adhere to the precipitated earth, such as the acetous or nitric; or as M. Vauquelin advises, by supersaturating with muriatic acid, so as to make a clear muriatic solution, and afterwards precipitating by carbonated ammonia.

Alumine is known to be free from sulphuric acid when a nitrated or muriated solution of it mixes uniformly with nitrated or muriated barytes, without precipitation. It is free from potash when, dissolved by sulphuric acid (being

* An. Chim. tom. 32.

† Handb. zur Chem. Analyse.

previously ignited to separate any ammonia), it becomes by evaporation nearly to dryness, an unctuous-looking mass, without giving any crystals of alum by repose for a day; as potash or ammonia are absolutely requisite to the formation of alum.

Alumine has a strong affinity for the vegetable and animal oils. Alum in solution, mixed with soap-water, curdles it completely, and the coagulum is an intimate union of this earth with the oil of the soap, forming a soft flexible mass, which, when dry, remains supple; is insoluble in alcohol, and, after fusion, becomes transparent.*

The attraction of clay of every kind for oil is shewn in the valuable cleansing powder called CIMOLITE, and the different kinds of FULLER'S EARTH.

The affinities of alumine for the acids are in the following order, viz. sulphuric, nitric, muriatic, oxalic, arsenic, fluoric, sebatic, tartareous, succinic, mucous, citric, phosphoric, formic, lactic, benzoic, acetous, boracic, sulphureous, nitrous, carbonic, prussic.

AMADOU. A combustible preparation, applied to the same uses on the Continent as tinder is among us. It is made chiefly in Germany, whence it is imported in large quantities to France. The basis of the amadou consists of the large spongy boleti that are found on the trunks of old oaks, alhes, and various other kinds of timber trees. As soon as gathered, they are boiled in plain water, to extract all the peculiar juices; this being done they are dried, and then well beaten with a wooden mallet, in order to render them soft: they are also by this means stretched, so as to be reduced to the thickness of strong buff leather. A boiling hot solution of nitre is now prepared, in which the boleti are immersed for a short time; they are then taken out, drained, and finally dried in an oven. Good amadou is of a yellowish brown colour; is soft to the touch like the finest felt, perfectly pliable, tough, and somewhat elastic. It takes fire like tinder, by a spark from the collision of a flint and steel, and burns slowly, but is very difficult to extinguish.†

AMALGAM, is a name given to the combinations of the other metals with MERCURY, which see.

AMALGAM Native. See SILVER, ores of. AMBER. *Bernstein*, Germ. *Succin*, *Carabé*, *Ambre Jaune*, Fr. *Electrum*, *Succinum*, Lat.

M. Werner describes two varieties of amber,

differing from each other in colour and transparency, but as there is no other perceptible distinction, we shall follow the example of most authors, and treat of amber as a single species.

The colour of this mineral is generally some shade of yellow, mixed more or less with reddish brown; it is found also occasionally green or yellowish white: it is usually transparent or semi-transparent, but when of a green or whitish colour it is nearly opaque. The lustre of the clearest kinds is very considerable; it is easily broken, and exhibits a perfectly conchoidal fracture, may be scratched by a knife with great ease, but cannot be marked by the nail. Its specific gravity varies from 1.078 to 1.1. It is found in nodules and rounded masses, from the size of coarse sand to that of a man's head, pieces of this latter magnitude are however extremely rare.

Amber occurs in detached pieces on the southern coast of the Baltic, on the eastern shores of England, and in small quantity upon those of Sicily and the Adriatic sea. It is occasionally found in the gravel beds near London, and near Sisteron, in Provence: in all these situations, however, it is merely an alluvial product, casually mixed with rounded pebbles. The only proper mines of this substance that have yet been discovered, are in Ducal Prussia, near the sea coast; these, in the reign of Frederic William, were examined by Hoffman, from whose account we have selected the following particulars.

The uppermost stratum is sand, underneath which lies a bed of clay, fifteen or sixteen feet in thickness; to this succeeds a stratum of trees, in some places forty or fifty feet thick, in a half decomposed state, impregnated with martial pyrites and bitumen, and of a blackish brown colour. In this stratum are occasionally found pieces of wood penetrated by veins of amber. The mineralized wood rests upon a bed of pyrites and sulphat of iron, among which are not unfrequently found stalactites of amber, adhering by one extremity to the under side of the trunks of the trees. Beneath the pyrites is a bed of coarse sand, in which is unbedded the principal part of the amber, in the form of rounded detached nodules, weighing sometimes from three to five pounds. The largest mass of amber that was ever discovered was met with incidentally, near the surface of the ground in Lithuania, about twelve miles from the Baltic sea: it weighs above eighteen pounds, and is

* Berthollet Mem. Sci. 1780.

† Thompson's System of Chim.

* Encyclopedic Arts & Metiers. art. Amadou.

now in the King's cabinet at Berlin. ^a The amber-mines are worked in the usual way by shafts and galleries to the depth of about a hundred feet. From these circumstances it appears sufficiently plain that amber originates from vegetable juices, probably of the terebinthinate kinds, which are gradually modified by the action of sulphuric acid. As a proof that the change, though considerable, has not been effected with violence, specimens of amber are not unfrequently met with, containing insects, which are generally supposed to be ants, but which, according to Bernard de Jussieu, are exotic insects, not natives of the European continent. ^b

When amber was in greater request as an ornament than it is now, great attention was paid to it by the German artists, and many experiments were made to remove its defects or improve its beauty. The coarser and smaller pieces were called *schlug*, and were principally employed for distillation; those that were a little larger and cleaner were made into varnish, and the best and largest pieces were fashioned into various ornaments, such as snuff-boxes, cane-heads, necklaces, &c. Of the transparent ambers, the bright golden yellow was the most esteemed; of the opaque varieties, the flaky or the scaly. Methods were discovered, especially by Gottlieb Samuelsson, of Breslaw, of rendering opaque amber transparent, and of tinging it red, blue, green and white. Most of these secrets have perished with their inventors, but the two following were the general methods of rendering amber transparent. First, by surrounding it with sand in an iron pot, and cementing it in a gentle heat for forty hours, some small pieces being occasionally taken out to judge of the progress of the operation. Secondly, which was the usual method, by digesting and boiling the amber for about twenty hours in rape-seed oil, by which it became both cleaner and harder; amber thus clarified, however, is much less electric than when in its natural state. ^c

Thales, one of the Greek philosophers, appears to have been the first person who discovered that amber when rubbed had the property of attracting straws, hairs and other light bodies; on which account he ascribed a kind of life to it. A number of analogous and connected phenomena have been added in modern times to this discovery of Thales, and the science hence resulting has been called *Electricity*,

from *Ηλεκτρον*, the Greek name for amber. From the attracting property and real beauty of this mineral, it was held in high estimation among the Romans, who made it into bracelets, and other articles of female ornament: those pieces that contained insects were then, as at present, the most valued. The superior lustre and hardness of gems, and the imitations of them in glass, have thrown amber ornaments entirely into disuse in Europe, though it still keeps up its value in Turkey and the East.

There are two substances that are liable to be confounded with amber, namely, COPAL and HONEYSTONE (*Honigstein*); they may be readily distinguished, however, by attention to the following properties. Copal is somewhat softer than amber, and when set on fire melts into drops, which amber does not. Honey-stone possesses a much weaker degree of electricity, and when laid on a hot coal, after a short time, gives out a smoke without any flame, and becomes white, without much sensible diminution of size.

Amber, during pulverization, gives out a slight not unpleasant odour, which becomes much stronger when the mass is heated or melted. It cannot be brought to a fluid state without a commencement of decomposition, and the volatilization of part of its acid: at a little higher temperature, if exposed to the air, it takes fire, and burns with a yellowish flame, mingled with blue and green, exhaling a dense pungent aromatic smoke; a light shining black coal is left behind, which with some difficulty is reducible to ashes. The proportion of residue varies considerably: from half a pound of amber, M. Bourdelin obtained, in one instance, $4\frac{1}{2}$ grains of ashes, and in another 12 grains. ^d

Water, whether cold or hot, has no effect on amber. Alcohol by long digestion, or still better by repeated distillation from finely pulverized amber, dissolves a small portion, and becomes of a deep reddish-brown colour, forming the *Tincture of Amber*. On the addition of a little water, the liquor turns opaque and milky, and a resinous matter is at length deposited. The efficacy of alcohol as a solvent of amber depends greatly on its purity, proof spirit having scarcely any action on this substance.

Levigated amber, by slow digestion with an equal weight of caustic potash dissolved in water, combines into a thick saponaceous mass, which is readily soluble both in water and spirit of wine; with the latter it forms the *Tinctura*

^a Tilloch's Journ. v. xviii. p. 93.

^b Tingry on Varnishes, v. i. p. 30.

^c Rees's New Cycloped. art. Amber.

^d Mem. de l'Acad. des Sciences, 1742, p. 192.

succini tartarizata, once an article of repute in the Materia Medica. According to Jacobi,^e the aqueous solution of amber and potash deposits, by slow evaporation, needle-form crystals, of a bitterish taste.

Neither the expressed nor volatile oils have any action on amber by common digestion, except this latter has been previously roasted or melted: when this is the case it is readily soluble in both kinds of oil, either separate or mixed, forming the base of the Amber VARNISHES. Hoffmann however found, that if one part of pulverized amber was put into a glass vessel, with two parts of oil of almonds, and the whole inclosed in a Papin's digester filled with water, the oil and amber in a short time united into a jelly-like mass. Ether has some action, though but slight, on amber.

Amber is unalterable by the weaker and diluted acids. When heated, however, with concentrated sulphuric acid, it is converted into a dark coloured resinous mass, at the same time that a quantity of volatile sulphureous acid is disengaged. Nitric acid attacks amber with great rapidity, accompanied by a very copious production of nitrous gas, and converts it into a light pulverulent resin, entirely soluble in dilute nitrous acid. If pounded amber is thrown into melted nitre, a considerable detonation takes place, and the residue is a greyish saline mass, which when dissolved in water, and subjected to spontaneous evaporation, deposits a soft slimy substance, mixed with slender prismatic crystals, consisting probably of the acid of amber combined with potash. The experiment appears to have been first made by Bourdelin, who, because the salt caused a precipitate with nitrat of silver, and emitted a white vapour with sulphuric acid, supposed it to be muriat of potash: if, however, the nitre which he used was pure, it is difficult to conceive how the muriatic acid could exist in the residue of the process. At all events it is a point worthy of being cleared up.

When amber is exposed to dry distillation in closed vessels, it swells, puffs up, and discharges a large quantity of carbonic acid and carburetted hydrogen: together with these gasses there comes over, first, a colourless empyreumatic watery fluid, with a peculiar, not disagreeable, odour, and containing a little acetous acid; this is called spirit of amber, *spiritus succini*: next follows a thin clear yellowish oil, smelling like petroleum, partly mixed with, and partly holding in solution, a crystalline salt, the *acid of amber*,

or *succinic acid*: as the distillation goes on, the oil becomes more coloured and of a thicker consistence, so that towards the end of the process, it is almost black and somewhat viscid. There remains in the retort an intensely black, shining coal, which is employed as the basis of the finest black varnish.

The *oil of amber* is separated from the acid with which it is mixed in the first distillation by washing with warm water, and may be further purified by subsequent rectification; the best method of effecting which is to distil the oil by a very gentle heat, having previously mixed it with a dilute solution of carbonated soda, in order to detain the acid. Carbonated potash, provided it is perfectly neutralized, will answer as well as soda, but if either alkali is at all caustic, the oil will be acted upon, and its quantity considerably diminished. The proportion of oil varies a little, according to the purity of the amber employed, but upon the average amounts, according to Neuman, to nearly two-thirds of the weight of the amber. The oil of amber is only used medicinally as an ingredient in EAU DE LUCE, which see.

We shall conclude this article with an account of the acid of amber or SUCCINIC ACID.

It has been already mentioned that the Succinic acid rises during the destructive distillation of amber, partly in the form of spicular crystals which attach themselves to the neck of the retort, and in part is dissolved in the volatile oil which rises at the same time. The acid in this state is of a dark yellowish brown colour, being contaminated by the oil, and requires successive rectification before it can be obtained tolerably pure. Two methods have been practiced of purifying the acid: the first is, to mix the brown concrete acid with sand, or still better with dry unburnt white clay, free from calcareous earth, and proceed to sublimation by a very gentle heat; the clay detains the most part of the oil, and the acid rises to the upper part of the vessel, where it forms light-brown needle-shaped crystals. The second, and more economical way, recommended by Pott,^f is first to wash the oil in warm water, in order to separate the acid held by it in solution; then after pouring off the oil to add the solid acid, and heat the water till the whole of it is dissolved; a filter of cotton wool moistened with oil of amber being now prepared, the hot solution is run through it; the oil is principally detained by the filter, and the fluid as it cools deposits long slender crystals of succinic acid, which may be

^e Act. Acad. Nat. Curios. v. ii. p. 243.

^f Mem. de l'Acad. des Sciences, 1753.

rendered still purer by subsequent solution and filtration, or still more effectually according to Lowitz,^s by the following method; make a saturated solution of the solid acid in hot water, and add a quantity of finely pulverized fresh burnt charcoal, equal to half the weight of the acid: strain the solution through a filter of charcoal powder, and as the liquor cools the acid will be deposited in long, clear, perfectly colourless crystals.

According to the German chemists, the proportion of acid yielded by amber is about one thirtieth of its weight; the French on the other hand, have not in general been able to obtain more than one sixtieth.

Purified succinic acid is very acid to the taste, though not corrosive: in very cold water it is scarcely at all soluble, requiring from 24 to 30 times its weight of this fluid at 50° Fahr. for its solution, of boiling water however three parts are sufficient. The form of its crystals is that of truncated three-sided prisms, or, when prepared in the manner recommended by Lowitz, of thin four-sided tables. A gentle heat is sufficient to volatilize this salt; it rises in white vapours like carbonated ammonia. It is neither efflorescent nor deliquescent when exposed to the air.

The base of succinic acid is a compound combustible one like the vegetable acids: it burns when exposed to the blow-pipe, detonates with nitre, and when succinat of potash is heated in close vessels, a large quantity of carburetted hydrogen is given out, and carbonated potash mixed with charcoal is left behind.^s

Boiling alcohol dissolves succinic acid in the proportion of 117 grains to an ounce, which is almost wholly deposited as the liquor grows cold. If the impure acid is dissolved in alcohol, and six times the quantity of cold water is added, the mixture becomes turbid and milky from the separation of the oil, and if in this state it is thrown upon a filter, a clear fluid holding the acid in solution passes through, and the oil remains behind on the filter.

Nitric acid dissolves the succinic acid, but does not convert it into oxalic acid, as was supposed by Weftrumb.

Potash combines readily with succinic acid, forming a neutral salt.

Succinat of potash, crystallizing in truncated trihedral prisms, which are somewhat deliquescent in the air, are readily soluble in water, have a bitterish saline taste, and decrepitate on

hot coals. Its acid is destroyed by heat, leaving the alkali in a carbonated state.

Succinat of soda differs from the former salt, in being permanent in the air, and less soluble in water.

Succinat of ammonia forms needle-shaped crystals of a sharp saline bitter taste: it may be volatilized and sublimed without decomposition. The fixed alkalies disengage the ammonia, and unite with the acid.

Succinic acid with lime and barytes forms salts of difficult solution in water. It unites with magnesia into a gummy uncrystallizable mass.

The affinities of succinic acid have not been determined with any accuracy on account of the difficulty of obtaining it pure, for any mixture of oil with the acid will greatly modify its action on other salts. According to Morveau,^h barytes has the most powerful attraction for succinic acid, after which come lime, the fixed alkalies, ammonia, and magnesia.

Grenⁱ arranges the affinities of succinic acid in the following manner: it decomposes in the moist way all the carbonated alkalies and earths.

All the earthy and alkaline succinats are decomposed by sulphuric acid.

The alkaline succinats are also decomposed by nitric, and muriatic, and fluoric acids, but nitrats, muriats, and fluats of lime and barytes, are decomposed by succinic acid.

The boracic, benzoic, and acetic acids, are inferior in affinity to the succinic acid.

AMBERGRIS (or *Grey Amber*, as it is sometimes called) is a grey, brittle, light inflammable amorphous substance, generally found floating on the surface of the ocean, or thrown on shore in all the southern seas frequented by the spermaceti whale. It is also occasionally met with in the intestine of the same animal, which circumstance, along with the corroborating testimony of whale-fishers, has very satisfactorily cleared up all the doubts that have been entertained as to the origin of this singular substance.

Ambergris is sometimes found in very large masses. The very accurate and faithful Neumann, in his elaborate history of Ambergris, published in the Philosophical Transactions for 1734, mentions a celebrated mass of ambergris thrown on shore on the island of Tidor, and purchased of the king of that island by the Dutch East India Company in 1693, for eleven thousand dollars, which weighed 182 lb. and

^s Crells Chem. Annalen. 1793. vol. i. p. 32.

^s Grens Syst. Handbuch, vol. iii. p. 22.

^h Journ. de Phy. vol. xxvi. p. 463. ⁱ Syst. Handbuch.

measured 5 feet 8 inches in length, and 2 feet 2 inches in thickness. It was long exhibited at Amsterdam, and at last broken up and sold. Other masses of many pounds weight have also been found floating on the sea. A captain in the Southern Whale Fishery, examined before the privy council in 1791,^a related that he found 362 ounces of this substance in the intestine of a female whale struck off the coast of Guinea; part of it was voided from the rectum on cutting up the blubber, and the remainder was collected within the intestinal canal. Dr. Swediaur in his valuable paper on this subject,^b also relates many authentic facts to the same purpose.

The whales that contain ambergris are always lean and sickly, yield but very little oil, and often seem almost torpid, so that when a spermaceti whale has this appearance, and does not dung on being harpooned, the fishers generally expect to find ambergris within it. It is uncertain whether this substance is the cause or effect of disease.

Another convincing proof of the origin of ambergris is, that it generally contains a number of hard bony fragments impacted within it, which are the beaks of the cuttle-fish, called by the seamen *squids*, on which the whale is known to feed, and which are always found mixed with the whale's excrements, more or less broken down in the intestinal canal.

The physical properties of ambergris are the following: its colour is ash-grey or brown, and somewhat mottled; its hardness sufficient to render it easily friable, but not to bear a polish; when broken down it has a soapy feel like stearite, and shews somewhat of a granulated texture. It has scarcely any taste. The smell of ambergris when recently taken from the whale, is very strong and rather fetid, but by keeping, the offensiveness goes off, and it acquires a faint musky odour. When heated or burned it liquefies, and gives that peculiar penetrating fragrant smell for which it is so much valued, and the same takes place when in solution or mixed with other scents; so that, like musk, it is too powerful for most organs till diluted or diffused in the air.

The specific gravity is from about .844° to .926,^d so that it floats both in salt and fresh water.

Several chemists have attempted the analysis of this substance, among whom are Neumann, Lemery, Hanckwitz, and lately La Grange.

Ambergris begins to melt at about 145°, at 212° it is volatilized in the form of white

vapours; if burnt in an open crucible it leaves scarcely any sensible residue; distilled in a retort, the products are an acidulous watery vapour, oil, and a concrete salt, and a bulky coal is left behind.

From the production of an acid and the excrementitious nature of ambergris, La Grange suspected this acid to be the benzoic. He accordingly treated it both by sublimation and by boiling with lime, according to Scheele's method of procuring the acid of benzoin, and obtained about a tenth of its weight of this acid salt. Water, hot or cold, has no sensible effect on ambergris, nor does it extract the acid, as it does partially from gum-benzoin. Acids have but little action on this substance. The nitric, however, when distilled from it, leaves a mass which dries into a yellow brittle transparent resin.

Caustic potash forms with it a species of soap, but disengages no ammonia. The oils, fixed and volatile, dissolve it without difficulty.

The operation of alcohol on ambergris is the most instructive. Neumann^e found that cold spirits dissolved but a small portion of this substance, but that it was entirely soluble in twelve times its weight of tartarised spirit of wine, assisted by a boiling heat, a small earthy residue excepted. On cooling and evaporation of the spirit a *sebaceous* matter separates, which Lemery took to be wax, and hence this chemist was led to suppose that ambergris itself was a product of bees, an hypothesis fully refuted by more accurate observation. La Grange in the paper above mentioned remarks precisely the same effects in the analysis by alcohol, and has examined them with more minuteness. Ambergris repeatedly digested with cold alcohol, yields a brownish tincture, till every thing soluble in this way is extracted. This tincture contains sufficient benzoic acid to redden litmus, and evaporated to dryness leaves a brown brittle resin, which may be entirely volatilized on hot coals, diffusing a very fragrant odour. The insoluble residue of the first tincture, being now digested in fresh spirit and heated to boiling, is almost entirely dissolved; but on cooling, the spirit deposits what it had taken up, in the form of a light, bulky mass, which a little dried, yields to the pressure of the finger, like curd, softens by heat, and has all the properties of *adipocire*. The trifling residue still left undissolved, appears to be a carbonaceous matter.

Ambergris is also soluble in ether.

The following composition of ambergris is

^a Phil. Trans. Vol. 81. ^b Phil. Trans. Vol. 73. ^c La Grange An. Ch. Tom. 47. ^d Briffon. ^e Phil. Trans. 1734.

given by La Grange, and probably approaches considerably to accuracy. One hundred parts contain

Adipocire - - -	52.
Refin - - -	30.
Benzoic acid - -	11.
Carbonaceous residue	5.
	—
	98
	—

The only use of ambergris in this country is in perfumery. The tincture in alcohol, or *essence*, is the preparation chiefly employed. This is of a very brown red when made with tartarised spirit, but brighter coloured when of pure spirit. A drop or two is mixed with a large quantity of lavender water in the shops, and adds much to the fragrance of its scent. It is employed to perfume tooth-powder, wash-balls, hair-powder, &c. It formerly made an article of the *Materia Medica*, but it is now entirely disused in most parts of Europe, having but little efficacy except in very large doses; when it proves purgative.^f The chief mart for ambergris is Turkey, Persia, and the East, where it is employed in cookery, medicine, perfumery, and for a purpose never forgotten by oriental nations, as an aphrodisiac, though its virtues in this particular are altogether imaginary.

The price of ambergris is very high. In London it is retailed at from twenty to twenty-four shillings the ounce, and hence its frequent adulteration with wax, benzoin, ladanum, meal, &c. scented with musk. It is not very easy however to imitate it accurately.

AMETHYST, a transparent gem of a violet purple colour, considerably esteemed by the ancients, but less so by the moderns. It is divided by the jewellers into two varieties, the oriental, or purple CORUNDUM, and the common, or purple QUARTZ.

AMIANTH or AMIANTHUS. See ASBEST.

AMIANTHINITE of Kirwan, see STRAHLSTEIN.

AMMONIA, Volatile Alkali. *Alkali fluctigies*, Germ. *Ammoniaque*, Fr.

The volatile alkali, an agent of high importance in chemistry, is remarkably distinguished from the other alkalies by its great volatility (as its name imports) by its weaker affinity to acids, by its powerful smell, by being only known in the gaseous form when pure, and by being certainly a compound substance.

Ammonia is obtained for actual use only from vegetable and animal substances, more

especially the latter; in a few instances that we shall presently mention, it is also formed by the union of its constituent parts in the course of certain chemical experiments. The distillation of animal or vegetable matter has long been known to furnish an ammoniacal product, partly liquid, partly concrete, and capable of being purified by subsequent rectification, which has been termed *salt or spirit of hartshorn, spirit of urine*, &c. according to the substance employed.

In all these cases the volatile alkali is disengaged in a carbonated state, and is accordingly strongly effervescent with acids. This subject we shall refer to the articles CARBONAT of *Ammonia*, and ANIMAL *Matter*, and we shall here only describe the properties of ammonia in its pure and caustic state, and the facts which prove its chemical composition. All these facts are comparatively modern; Dr. Black first pointed out the difference between the caustic and mild alkalies, and the respective states of ammonia among the rest. And Dr. Priestley appears to have been the first who obtained this alkali in its purest form, that of a gas, and has termed it, *alkaline air*.

Ammonia is thus prepared: take any quantity of well-burnt lime, slack it with a little water, so as to reduce it to powder, then mix it expeditiously with half its weight of dry muriated ammonia in fine powder. On the instant of mixture, very pungent suffocating fumes of volatile alkali will be disengaged (which should be avoided as they would excoriate the nostrils) and the mixture should be put into a retort of glass or earth, or into an iron or earthen tube, closed at one end, and closely fitted with a stopper, to which a bent glass tube is cemented. On the application of a very moderate heat, by a lamp or a pan of charcoal, the ammoniacal gas will be given off in great abundance for a considerable time, and to be examined chemically must be received in a jar filled with mercury and standing over the same fluid.

In this operation the ammonia is displaced from the muriatic acid by the lime, so that after all the alkali has been expelled, muriat of lime with a great excess of lime remains in the retort. This when duly heated is phosphoric. (See PHOSPHORUS, *Baldwin's*.)

A much smaller quantity of lime is sufficient for the expulsion of the ammonia. Mr. Cornette^a found by direct experiment that when equal parts of lime and muriated ammonia were used, all the alkali was given out by heat, and in the residue which contained no undecomposed mu-

^f Swediaur.

^a Mem. de Acad. des Sciences, 1786.

riated ammonia, nearly a fifth of the lime still remained uncombined. On using three times the quantity of lime, no more ammonia was obtained than with only equal parts.

Many other substances will decompose muriated ammonia and expel the alkali. The oxyds of lead, minium, and litharge, assisted by heat, may be used with advantage, and the residue is then muriated lead. Water absorbs ammoniacal gas with great ease, but yields it again when heated to about 130° and hence the liquid ammonia affords a very ready method of furnishing the gaseous alkali, nothing more being necessary than to put the liquor into a proof bottle with a curved tube, or any similar vessel, to heat it with the flame of a taper, and to collect the gas over mercury. No greater heat than necessary should be used, otherwise the steam of the water driven over along with the gas, will absorb it again rapidly on cooling.

Ammonia remains a permanent gas unaltered at any known temperature under a red heat. In this state it is intensely pungent and caustic, excoriating the nostrils when snuffed up unmixed, producing a most acrid sensation to the tongue and a dangerous constriction of the larynx. In a dilute form it is gratefully pungent and refreshing. Small animals immersed in it are instantly killed. The specific gravity of ammonia is not easily ascertained with perfect accuracy, owing to the extreme ease with which this gas combines with moisture in large proportions.

According to Mr. Kirwan's experiments,^b 100 cubic inches of this gas at 61° temperature, and 30 inches barometrical pressure, weigh 18.16 grains. The same quantity of common air he estimates at 31 grains, and hence the alkaline air is lighter than common air in the proportion of about 6:10. Therefore as the specific gravity of common air (being 816 times lighter than water) is .0012255, the specific gravity of ammonia is .0007353. Other experiments nearly agree with this estimation of alkaline air.

This gas has been commonly represented as remarkably dilatible by heat, much more so than common air in similar circumstances. This has been actually observed by Priestley, Guyton, and other chemists, but it appears to apply only to this gas in its *common* state. The experiments of M. du Vernois^c prove that much of this expansion by heat is owing to the quantity of water that is vaporized along with the alkali, which quantity being variable, throws an equal irregularity on the results.

He attempts however to give the following comparison as an approximation to the truth. 100 cubic inches of common air at 32° and the same quantity of ammoniacal gas (procured from dry muriated ammonia and lime) also at 32° are respectively expanded at different temperatures in the following ratio.

	common air.	ammon. gas.
at 77°	107.89	127.91
122°	125.70	184.87
167	165.74	358.78
212	193.68	680.09

But independently of the error arising from the admixture of aqueous vapour, it has been supposed that even in the heat of boiling water, a small portion of the alkaline gas is decomposed by the mercury over which it is confined, and which is generally slightly oxydated at the surface, and we shall presently see how readily the metallic oxyds act upon the alkali.

Mr. Gay-Lussac, in his valuable experiments on the dilatation of gasses^d gives another cause of error in the experiments on alkaline air. In receiving the gas *directly* from the mixture of lime and muriated ammonia, he did indeed find it much more dilatible by heat than common air, but on cooling the gas he observed it to deposit a liquid, with crystalline points of a salt which he took to be either muriat or carbonat of ammonia, all of which again disappeared on raising the temperature. To exclude this impurity he repeated the experiment with ammonia that had previously remained in contact with potash, and now no longer gave this deposition on cooling. This gas was now found to expand *exactly in the same ratio as common air* by equal increments of heat from the freezing point to 203° .

A high heat decomposes the alkali as will presently be seen.

Ammoniacal gas extinguishes fire. When a lighted taper is plunged into a jar full of this air, it immediately goes out, but just before extinction, the flame is enlarged by a kind of halo of a pale yellow colour.^e The electric spark taken in it is red.

Ammonia combines with extreme rapidity with water, the easier as the water is colder. Heat is given out at the same time. Ice absorbs this gas with equal facility, and in so doing it appears to melt as fast as if a red hot iron were applied to it. Mr. Davy's experiments on this subject are useful, and bear the marks of every practicable degree of accuracy.^f

^b Essay on Phlogiston.

^c Encyc. Meth. art. Air.

^d An. Chem. tom. 43.

^e Priestley.

^f Researches.

This chemist found that 50 grains of water absorbed 17 grains of gaseous ammonia (rather more than a third of its weight, and according to the calculation given above, nearly 463 times its bulk) and by this absorption the bulk of the liquid was much increased, or in other words its specific gravity was diminished. Therefore the levity of such a solution is in direct proportion to its strength of alkaline impregnation.

By calculation from two extreme terms Mr. Davy gives the following table of specific gravity of liquid ammonia, corresponding with the respective quantities of alkali and water in the solution. As this preparation is in constant use we shall give the table, which may be of service in ascertaining its strength, and regulating the price which it should bear. The temperature is assumed to be 52° , but the changes in specific gravity from 40° to 65° are not materially different.

100 parts (by weight) of liquid ammonia of

spec. gr.	ammonia.	water.
.9054 contain	25.37 and	74.63
.9166 ———	22.07 —	77.93
.9255 ———	19.54 —	80.46
.9326 ———	17.52 —	82.48
.9385 ———	15.88 —	84.12
.9435 ———	14.53 —	85.47
.9476 ———	13.46 —	86.54
.9513 ———	12.40 —	87.60
.9545 ———	11.56 —	88.44
.9573 ———	10.82 —	89.18
.9597 ———	10.17 —	89.83
.9619 ———	9.60 —	90.40
.9684 ———	9.50 —	90.5
.9639 ———	9.09 —	90.91
.9713 ———	7.17 —	92.83

Liquid ammonia (the *aqua ammonia pura* of the pharmacopœias) is actually prepared from the same materials in two ways; in one, the liquid itself is distilled; in the other, the gas is received in water and there absorbed. The former is the oldest method, and is still practised very largely. It is the following slack two pounds of well-burnt quick lime, with one pint of water; when thus reduced to powder, mix it with sixteen ounces of muriated ammonia, already in powder, put it into a retort, add five pints of cold water, and lute on a receiver, capable of being kept extremely cool, if possible surrounded with ice. Then distil off, with a moderate heat, twenty ounces of the liquid, which will be the liquid ammonia, or caustic volatile alkali. It is to be observed that

the ammonia is so much more volatile than water, that the whole of it comes over with the first pint or pint and a quarter of water, so that no advantage whatever is gained by continuing the distillation any longer. The rest of the water serves to keep the residue sufficiently liquid to be readily taken out of the retort. Twice as much lime as necessary is employed, but this excess serves to keep down any carbonic acid that might otherwise rise. The specific gravity of the liquid thus prepared is about .936, and contains about 17 per cent. of ammonia.^a The process should be conducted slowly, and the receiver kept very cool, or else the water will again part with the alkali, and this latter, escaping in the form of gas, may burst the vessels if tight, or run to waste if open.

The other method, which is neater and probably better in every respect, is to receive the gas from the lime and sal ammoniac, in a known quantity of water, which will absorb it till saturated. No more water, therefore, should be added to the materials than is just sufficient to slack the lime, (about half its weight); and to make as strong a solution as can conveniently be kept in a summer heat, as much water should be employed to absorb the ammonia as the weight of the muriated ammonia put into the distilling vessel. This last, instead of a wide neck, should terminate in a bent tube, plunged to the bottom of the water, and an apparatus similar to that of Woulfe's, to prevent absorption. If the receiving bottle is surrounded with ice, the retort may be heated pretty rapidly.

As this liquid speedily absorbs carbonic acid from the air, it should be kept in well closed bottles. The effect of heat upon it has been already mentioned to be the entire expulsion of the ammonia in form of gas, and nothing but pure water is left.

The effect of cold is singular. If cooled very low it loses much of the pungency of its smell (the alkali not being then so easily given off); and at last at the temperature of freezing mercury (-40), it begins to crystallize in brilliant flexible needles; or if more hastily cooled to this intense degree, or even still lower, it becomes grey, semitransparent like glue, or like filix in its gelatinous-precipitate form, and with scarcely any scent.^b

Many other liquids will absorb ammoniacal gas. Alcohol does it with great ease, and appears but little altered by it.

We shall now relate some of the numerous experiments that incontestibly prove that am-

^a Duncan's Edinb. Dispens.

Fourcroy An. Chem. tom. 43.

monia is a compound substance, which are both analytical and synthetical, this alkali being decomposed in a variety of processes, and in a few, being formed by direct union of its constituent parts.

Dr. Priestley's experiments¹ are among the first in the decomposition of this alkali. On passing the electric spark through this gas, he found it to be permanently enlarged after every shock, and when water was admitted, just so much remained unabsobered as had been added by the explosions. The air was now strongly inflammable, detonating when mixed with common air, as violently as the inflammable air from metals. The colour of the electric spark was red in this air, as in hydrogen. The extent of dilatation, Dr. Priestley found to be about three times the original bulk of the ammoniacal gas, and when at its extreme degree, no portion of the electrized air was now absorbed by water. He afterwards found that mere heat would produce a similar effect, though less perfectly, for on passing alkaline air through a red hot tube, part of it was changed to inflammable air, and part went through unaltered. Inflammable air, or hydrogen, is therefore thus proved to be one constituent of ammonia. The other is detected by the following beautiful and simple experiment. Having previously found that the oxyds of lead were revived when heated in inflammable air, Dr. Priestley tried the same with ammoniacal gas, and found that massicot (an oxyd of lead) was thereby reduced to reguline lead, with a certain diminution of the air, but not so complete as when hydrogen alone was employed; for the alkaline air, after it would reduce no more of the metal, left a large residue, which Dr. Priestley, to his surprise, found to be *phlogisticated* or azotic air. Red mercurial oxyd was in like manner reduced in alkaline air; water was generated in a very sensible quantity, and the residue, as before, was azotic, mixed with some oxygen gas from the mercurial oxyd. These experiments of the electrization of ammonia, and of reduction of metallic oxyds, have been confirmed by many other chemists.

The partial decomposition of volatile alkali by metallic oxyds did not escape the acute observation of Scheele. This eminent chemist observed² that liquid ammonia, when suffered to remain in contact with oxyd of manganese and nitrous acid, was entirely decomposed, and furnished an elastic gas, whilst the oxyd of manganese was so far reduced to the metallic state as to become soluble in the nitrous acid. The

ammonia therefore furnished hydrogen to the oxyd, to separate it in the form of water from this metal, and the other part of the ammonia, the azot, escaped in a gaseous form. Acid of arsenic and ammonia were found to undergo a similar change. (See MANGANESE and ARSENIC.)

But the most accurate and convincing experiments on this alkali were undertaken by M. Berthollet, on the facts discovered by Priestley and Scheele. M. Berthollet³ first ascertained that on the distillation of nitrous ammonia more water was produced than belonged to the crystallization of the salt, and that the source of this water was the mutual decomposition of the acid and the alkali, the former supplying the oxygen, and the latter, the hydrogen. See NITRATE OF AMMONIA.)

M. Berthollet also repeated the experiment of the reduction of metallic oxyds on ammonia. Oxyd of copper dissolved in this alkali, evaporated to dryness and afterwards strongly heated, became completely reduced; water was formed, and azotic gas given out, together with some ammonia that had escaped decomposition. Hence M. Berthollet beautifully explained the detonation of fulminating gold, and even confirmed it by actual experiment in close vessels. This preparation is oxyd of gold combined with ammonia; when heated it detonates vehemently, the gold is reduced, water is suddenly formed, and azotic gas given out. (See GOLD-Fulminating.)

Another singular phenomenon, also observed by M. Berthollet, is explained by the decomposition of ammonia. When oxymuriatic acid is mixed with liquid ammonia, a strong effervescence takes place, though the alkali contains no carbonic acid; a gas is given out, and the acid immediately loses its characteristic properties, becoming simple muriatic acid. This is beautifully explained by the decomposition of ammonia, the hydrogen of the alkali uniting with the excess of oxygen in the acid into water, and the azot of the alkali appearing uncombined in a gaseous form, for the effervescing gas when examined is found to be azotic. (See OXYMURIATIC Acid.)

A croud of interesting experiments, subsequent to these above mentioned, come in confirmation of this hypothesis of the decomposition of ammonia. M. Fourcroy, on passing the oxymuriatic acid gas⁴ into liquid ammonia, obtained a large quantity of azotic gas, which was collected in the pneumatic trough. On adding ammoniacal gas to oxymuriatic gas,⁵ a

¹ Expts. on Air, vol. ii. ² Essays. ³ Mem. de l'Ac. des Sciences, 1785. ⁴ An. Chim. tom. i. ⁵ An. Chim. tom. 4.

white flame was produced, and water was immediately seen trickling down the sides of the vessel.

The same chemist has also pursued the experiments with ammonia and metallic oxyds.^o Liquid ammonia added to nitrated mercury in solution, precipitates the metal black, and nearly metallic, and azotic gas is given out. The same takes place more strikingly with liquid ammonia and the red mercurial oxyd in powder. A strong effervescence of azotic gas takes place, the oxyd turns first white, then black, and on being moderately heated becomes mostly running mercury. The black oxyd of manganese moistened with ammonia in like manner effervesces slightly even at a cold temperature, the metal is partially reduced and becomes grey, and azotic gas is formed.

Nitrated iron treated with ammonia, is equally reduced to the state of the least oxydation, and the precipitate is the black oxyd of iron.

Many of the neutral ammoniacal salts when strongly heated, are partly sublimed and partly decomposed. The nitrated ammonia has been already mentioned. Mr. Chenevix^p found that the sulphated ammonia being distilled *per se*, gave out first, water of crystallization, then part of the salt sublimed unaltered, after which came over sulphureous acid and *azotic gas*, which continued to the end of the process.

The alkali of muriated ammonia, though not easily destructible by mere heat, is entirely decomposed by the nitric acid. Mr. Woulfe,^r by distilling one pound of nitric acid from four ounces of muriated ammonia, found the acid to act with great vehemence on the salt, and the whole contents of the retort were distilled over in a liquid form, in which no trace of undecomposed ammonia could be detected. The nitric acid was also in part decomposed, and much azotic gas, mixed with some oxygen, was given out in the process.

It often happens that in the decomposition of the alkali, the azot, which is one of the constituents of ammonia, instead of being given out in the form of gas, enters into new combinations, particularly with oxygen when present in excess, and forms *Nitrous Acid*. The particulars of this singular conversion will be given under this article, but it may be mentioned here, that Dr. Milner produced this acid by passing ammonia through heated oxyd of manganese; Fourcroy the same, by ammonia and sulphat of mercury; and Proust the same, by strongly heating a mixture of ammoniacal gas with an excess of oxy-

gen. If a smaller quantity of oxygen is used, the product of the gasses, after detonation in a high heat, is merely water and azotic gas.

We have now to mention some of the experiments in which ammonia is produced by the mixture of its constituent parts.

Animal putrefaction, and the disorganization of all animal and many vegetable substances by fire, are processes of this kind, that are perpetually going on, for in neither instance can ammonia be traced in the substance in any notable quantity, before putrefaction or combustion. (See *ANIMAL Matter*.) But chemistry furnishes us with more direct experiments.

An ammoniacal smell has often been observed accidentally by several chemists, where it was not expected; and more particularly in experiments with nitrous gas or acids, and various metallic oxyds. This was noticed by Dr. Priestley, in a solution of nitrated copper, mixed with iron filings, which had long stood together. Mr. Haussman, of Colmar,^r has shewn the same production of alkali, on mixing nitrous gas with the precipitate from acetite of iron. In this case the nitrous gas is rapidly absorbed by the iron precipitate, and at that time such an interchange of principles takes place, that a small portion of nitrated ammonia is formed in the mixture. On adding lime or caustic potash, the ammonia is expelled, and becomes sensible to the smell. A like production of volatile alkali always takes place when the green sulphat of iron is saturated with nitrous gas. This curious fact, which depends on very complicated affinities, will be explained in the article *NITROUS Gas*. It will be sufficient to observe, in this place, that the azot of the ammonia is provided for in the nitrous gas, and the hydrogen in the decomposed water of the solution.

Dr. Austin's experiments on the formation of ammonia are highly interesting.^t Dr. A. found, that no mixture of the two constituents, hydrogen and azot, when both in a gaseous form, could be brought to unite into ammonia, either by mixture in any proportion, or by any third addition. Even when the two gasses were the identical parts of a given quantity of ammonia, decomposed by electricity, they could not again be re-united in their alkaline form. Dr. A. attributes this, probably with reason, to the great difference of specific gravity between the two gasses, and hence he was led to attempt an union between the two, by putting

^o An. Ch. tom. 2.

^p Phil. Transf. vol. 86 p. 315.

^r J. Physf. tom. 31.

^t J. Physf. tom. 31.

^r J. Physf. tom. 30, for 1787.

^t Phil. Transf. for 1788.

the hydrogen in contact with azotic gas at the instant of its formation, before it had perfectly assumed the form of hydrogen gas, or as it is termed in its *nascent state*. This method succeeded. Iron filings, which are known to yield hydrogen soon after mixture with water, were moistened, and inclosed in an atmosphere of azotic gas. In about twenty-four hours ammoniacal gas was detected, by the usual test of changing to green a piece of blue-stained paper, which was suspended in the vessel. The green of nitrated copper on paper was also changed to blue, by the same process, in a few days. The same generation of ammonia took place in a few hours, when nitrous gas was substituted for the azotic. On the other hand the same change occurred, though in a longer time, when common air was used instead of the azotic. Hence it would follow that a small portion of ammonia is always produced whenever iron rusts in the open air, or generally by every natural process which evolves hydrogen.

We have already mentioned the formation of volatile alkali by nitrous gas, and several metallic oxyds, and referred the reader to the article nitric acid. In the following simple experiment this alkali is produced immediately in a very sensible quantity. Pour some moderately strong nitrous acid upon an ounce or two of tin filings, sufficient to moisten them completely, and stir them together; the action will be immediate and vehement, and copious fumes of nitrous gas will arise; a very short time afterwards add some lime or dry caustic alkali, rub them together, and a very pungent smell of ammonia will be given out. In this experiment the ammonia which is formed from the decomposition both of nitrous acid and of water, first unites with another part of the acid, forming nitrated ammonia, which might be procured as such from the mixture. Then, on adding the lime, this newly formed salt is again decomposed, and the volatile alkali is expelled in its gaseous form. Zinc filings, moistened with nitrated copper, and mixed with lime, equally give out ammonia.

The method which has been pursued by M. Berthollet, and succeeding chemists, of ascertaining the relative proportion of the two ingredients of ammonia (and indeed the only one practicable) has been first to resolve ammoniacal gas into its constituent parts, hydrogen and azotic gases (for which electricity offers a certain but tedious agent), and then to abstract the hydrogen by detonation with oxygen in Volta's eudiometer. The perfect resolution of

the ammonia after electrization over mercury, is known by the enlargement ceasing, and by the electrized gas being now entirely unabsorbed when water is thrown up to it. In the subsequent detonation of the hydrogen (in which an excess of oxygen should be employed) a great portion of the gas disappears; which loss, as it is accounted for by the production of water, must be estimated according to the known proportions in which hydrogen and oxygen constitute this fluid. The remaining gas (allowing for the excess of oxygen employed) is the azot, the other constituent of the ammonia. In this manner M. Berthollet estimates the composition of ammonia to be 121 by weight of azot, and 29 of hydrogen; supposing too that the comparative specific gravity of the former to the latter is as 11 to 1.

Mr. Davy^u in his experiments decomposed his ammonia by transmission through a red hot tube of green glass; after which he estimated the hydrogen and azot in the manner above-mentioned, and the result coincided almost exactly with that of M. Berthollet.

An approximation to the same result is afforded by calculation from the known specific gravities of all the airs concerned in these experiments.^v According to Mr. Kirwan, 100 cubic inches of alkaline air weigh 18.16 grains, of azotic air weigh 30.535 grains, and of hydrogen gas weigh 2.613 grains. M. Berthollet reckons that 1.7 cubic inches of ammonia, expands by electrization to 3.3, and consequently 100 cubic inches of the electrized air now weighs only 9.355 grains: and by subsequent calculation, Dr. Austin found that a mixture of this specific gravity is formed by 121 grains of azot and 32 of hydrogen.

Considering the difficulty of obtaining a perfect uniformity in comparative experiments of this nature, in a gas so greedy of moisture as ammonia is, this coincidence is very satisfactory, and we may therefore conclude, without danger of considerable error, that 100 grains of pure ammonia are composed of about 80 grains of azot and 20 of hydrogen.

Ammonia combines with great ease with all the acids, forming neutral salts, which will be described under the respective acids. Its affinity for acids is weak, compared to that of the other alkalies and many of the earths. It is a remarkable property of this alkali that in many instances, when added to earthy or metallic salts, where its affinity to the acid is on the whole greater than the basis already combined, it only partially

* Researches.

* Austin Ph. Transf.

decomposes them, uniting with the remainder of the salt into a triple compound, sometimes crystallizable, consisting of the acid, the earth or metallic oxyd, and ammonia. It is of importance to be aware of this in chemical analysis. The affinity of magnesia, for example, is so nearly the same as that of ammonia to acids, that ammoniaco-magnesian triple salts are constantly occurring when the three substances come together.

The frequent decomposition of ammonia upon metallic oxyds, reducing them from the highest state of oxydation to the lowest, or even to the reguline state, has already been mentioned, when describing the facts that prove the decomposition of this alkali. It also simply dissolves other metallic oxyds, as copper, cobalt, zinc, nickel, tungsten, &c. Some of these compounds are crystallizable.

When ammoniacal gas is mixed with some of the gaseous acids, the carbonic or muriatic for example, a most beautiful phenomenon occurs: the two gases instantly on mixture form a dense white cloud, totally lose their gaseous form, and condense into minute flakes of the dry crystallized ammoniacal salt, so that, if pure, not an atom of gas is left in the vessel in which they are mixed. A rapid and complete absorption therefore is the consequence, and this is attended with a very sensible evolution of heat. See CARBONAT and MURIAT of ammonia.

This circumstance affords a very delicate test of ammonia, for if any of the alkaline gas is given off from any substance (suppose an uncorked bottle of liquid ammonia,) and a glass rod, straw, or any thing of the kind be only moistened with muriatic or nitrous acid, and held in the ammoniacal atmosphere, the alkali floating in the air will immediately be detected by the thick white cloud of nitrated or muriated ammonia, which will be seen to hover round the acid. This test is even more delicate than the smell.

The caustic powers of the volatile alkali are much inferior to those of the two fixed. It does not readily corrode animal matter. With oil it unites readily to a certain degree, but not so firmly and perfectly as the fixed alkalies. (See SOAP *Ammoniacal*.)

Sulphur may be made to combine with ammonia by distillation. Some interesting products are the result, which will be described under the article SULPHURET.

The constant tendency of ammonia to assume the gaseous state, in a very moderate heat, forms a considerable obstacle to its union with many

bodies with which the fixed alkalies may be made to combine; of course there can be no such substance as an ammoniacal glass.

PRUSSIAN *Blue* is one of the most curious combinations of ammonia that we are acquainted with.

Ammonia in its caustic state is used only in medicine and in the laboratory. Ammoniacal gas is one of the best correctors to the dangerous suffocating properties of the vapour of oxymuriatic, and probably of other acids. In the event of such an accident, the speediest method will be to mix quick lime and muriated ammonia with a little water, and to place the vessel containing it on the floor, as near to the feet of the sufferer as can be borne with security, so as to allow him to inhale cautiously some of the ascending ammoniacal gas, which will be given off in great abundance.

Ammoniacal gas is detected, as we have before mentioned, by giving a dense white fume with muriatic acid vapour. It is known to be pure when it is totally and instantly absorbed by water. This test is in general sufficient, for the other rapidly absorbable gases are the aeriform acids, which cannot remain in a gaseous state along with ammonia. If a small admixture of sulphuretted hydrogen gas be suspected, the test of acetited lead may be used, which will be blackened by water that has absorbed this gas, but not by liquid ammonia. The solution of ammonia in water is known to be perfectly deprived of carbonic acid when it gives no effervescence with acids, no cloudiness on mixture with strong alcohol, and particularly when it does not alter the transparency of a solution of pure lime (calcareous spar or Carrara marble) in the nitrous, muriatic, or acetic acids. This last, which is a most delicate test, should be made in a well corked bottle, for though pure ammonia will not precipitate lime, carbonated ammonia will do it very readily, and the alkali, if exposed to the air, will speedily absorb from it sufficient carbonic acid to render this test fallacious. If muriated ammonia is accidentally mixed with liquid ammonia in the process of distillation, the presence of the muriatic acid is thus detected: saturate part of the liquor with pure distilled vinegar, and add to it a few drops of nitrated silver, a white precipitate of luna cornea will then indicate the muriatic acid, for nitrated silver is not clouded by pure acetited ammonia. We may add, that in the analysis of any substance supposed to contain an ammoniacal salt, this alkali is best expelled by adding lime to the substance to be analysed, and

distilling the whole in a close vessel. The whole of the ammonia then comes over with the very first products, and if condensed by a little water in a cool receiver, it is thus obtained in a concentrated state, convenient for further examination. An example of this method is given in the analysis of ALUM.

The affinities of ammonia are the same as those of POTASH and Soda in the moist way, but the tendency of the volatile alkali to gasification on the application of heat, is so strong as to throw some uncertainty on its relative affinities, even at a moderately elevated temperature.

AMMONIURET. This term has been used of late to express the solution of any substance in ammonia, as *Ammoniuret of copper, of cobalt, &c.*

AMNIOS, *Liquor of the—Liquor Amnii.* Is the fluid contained within the membranes of the foetus of viviparous animals before birth. The unborn animal floats freely in the liquor amnii, and is therefore always in contact with it, till the time of parturition, when the membranes containing it are broken and the fluid escapes. It appears to be secreted by the inner surface of the membrane itself, and physiologists have not been able to ascertain, with much probability, any other use for it than to afford a protection to the foetus from external injury whilst in the womb, and a convenient medium in which the incipient animal may grow and encrease without confinement.

The more obvious chemical properties of the liquor of the amnios have been noticed by several writers: we are indebted to Messrs. Buniva and Vauquelin for a considerably minute analysis of this liquor, both human and from the cow, which appear to differ essentially in character.*

The human liquor amnii is slightly saline to the taste, and somewhat turbid in appearance, owing to the suspension of a kind of caseous matter, which is probably the same that adheres to the skin of new-born infants. This liquor froths by agitation, is heavier than water, its specific gravity being 1.005, and when heated becomes somewhat opake, like milk much diluted with water. The analysis by reagents, and by evaporation, presents nothing particularly interesting. By far the greater part is mere water, the other ingredients amounting to no more than $\frac{1}{12000}$ of the whole, and of this a part is albumen, together with muriat of soda, phosphat of lime, and a small excess of soda. In consequence of this last circumstance, it is

found to give a green to tincture of violets, and yet it slightly reddens tincture of litmus, as if an acid were present in excess, but the latter test appears not always so certain as the former. The liquor becomes slightly putrid by long keeping.

The liquor amnii of the cow differs from the human in being slightly red, having an acid taste with some bitterness, a smell similar to vegetable extract, a greater density, being 1.028 in specific gravity, and much more viscid.

Examined chemically, it strongly reddens tincture of litmus, gives a copious precipitate with muriated barytes, and an abundant red precipitate with alcohol. Evaporated, a thick scum separates, which on cooling is covered with white crystalline blades, and when reduced to about a fourth of its bulk and cooled, much of this crystalline matter is collected, and appears to be a concrete acid, differing from the other known substances of this class, and has been termed by the discoverers the *amniotic acid*. It may be also obtained in a purer state by evaporating the whole liquor to a very thick consistence, and treating the residue with boiling alcohol, successively added. On evaporating the spirit the acid is left pure. A thick pitch-like substance remains untouched by the alcohol, which is an animal extract somewhat peculiar. It has a very singular undescribable taste, is very soluble in water, and causes it to froth on agitation. This property, together with its insolubility in alcohol, gives this extract a resemblance to animal gelly, but it differs in not combining with tannin. When burned it gives ammonia, an empyreumatic oil, a prussic acid, and leaves a bulky coal, easy to burn, which furnishes a white ash, containing the phosphats of magnesia and lime.

The liquor amnii likewise contains sulphat of soda, which is separated from it in regular crystals when the evaporation is carried to a syrupy consistence. It may also be obtained by calcining the entire residue and subsequent lixiviation.

The amniotic acid above mentioned is a concrete white crystalline substance, somewhat sour to the taste, reddening litmus, soluble sparingly in cold water, abundantly in hot water, but mostly crystallizing again on cooling. It readily unites with the alkalies when caustic, and the salt thence resulting is much more soluble in water than the acid singly. The other acids again separate it from its alkaline combinations, in the form of a white shining powder. It does

* An. Chim. tom. 33.

not decompose, except heated, the alkaline carbonates. It has no sensible effect on the solutions of silver, lead, or mercury. On calcination it swells, and gives out a smell of ammonia mixed with that of the prussic acid. Though it agrees with some other of the crystallizable acids in many of its properties, it does not correspond in all with any one of them, so that at present it must be considered as a peculiar acid. Azot is one of its constituent parts, as it furnishes ammonia by heat. The quantity hitherto examined has been very small, as it is contained in the liquor of the amnios, but sparingly.

AMPHIBOLE of Haüy. See HORNBLÉNDE.

AMPHIGENE of Haüy. See LEUCIT.

AMYGDALOID. See MANDELSTEIN.

ANALCIME of Haüy. See ZEOLITE.

ANALYSIS is the separation of any substance into its component parts, with the view of ascertaining their nature, relative proportion, and mode of union. As every operation in chemistry is attended with a disunion of parts, the formation of new compounds is almost an invariable consequence; and hence the business of analysis is intimately connected with the whole of chemical science, and can only be thoroughly understood by one who is well versed in every branch of chemistry. Hence it becomes impracticable to draw up precise rules for every circumstance of analysis in less compass than would include the whole of operative chemistry, but we may allow ourselves some observations on the specific objects to be attained in conducting these processes, and the general principles on which they are to be pursued.

It would appear incredible that such an infinite variety of substances, all differing from each other both in physical and chemical properties, should be produced from a very few simple substances, if we did not know that every compound of elementary parts acquires by its union new properties which did not belong to either of its constituents taken separately. Hence a compound once formed, perpetually acquires the powers of an element, in being again able to unite, undecomposed, with other bodies, simple or compounded, in various proportions; and thus to produce new substances, in which the constituents often retain their original affinities, and in analysis again separate into their first elementary combinations. Thus the crystallized salt, nitrat of ammonia, is composed of nitric acid, ammonia, and water, each of which is itself compound, but in this particular combination acts as an elementary body.

For nitric acid consists of azot and oxygen,
 ammonia — of azot and hydrogen,
 and water — of oxygen & hydrogen;
 so that the elements of nitrated ammonia are simply azot, hydrogen, and oxygen; but it is requisite that they should first be combined into the acid, alkali and water, before this specific neutral salt can be formed.

The business of chemical analysis is to resolve a body into its constituent parts, but it is always an individual question belonging to every process of analysis, to determine whether this resolution should proceed to entire separation into real elements, or only into those compounds which act the part of intermediate elements, that is, whether disjunction or disorganization be required: as for example in the instance before us, whether nitrated ammonia be resolved into azot, hydrogen, and oxygen, or into nitric acid, ammonia and water. The former mode of analysis is in general the best calculated for experimental research, the latter for utility; but, however, a mixture of the two methods is commonly adopted, where the proportion and nature of the compound produced has already been fully ascertained by previous experiment.

Hence the infinite importance of accurate tables of the composition of all the pro-elementary substances usually met with, as by them we are enabled to simplify analysis, and to reduce it to much greater certainty. When we already know the composition of water, of ammonia, of the acids, of neutral or metallic salts, and the like, we may be satisfied with bringing the results of our analytical experiments to this point, and may deduce the rest from our tables; if we know that a hundred parts of luna cornea, dried at a certain heat, always contain seventy-five parts of silver, we may calculate on this proportion of metal, and save the further trouble of reduction. This mode of proceeding, however, requires considerable caution.

The most rigid proof of the accuracy of analysis is by *synthesis*, or by again producing the same compound, on uniting the identical parts which we have given as its constituents. It is but seldom that we are able to exhibit this proof in a perfectly satisfactory manner; we may oftener, however, reproduce a substance resembling that which we have analysed, by employing *similar* constituents, if not the *identical* substances. But even this proof is almost totally wanting in the analysis of the organized vegetable or animal matters, especially when reduced to their ultimate elements, and generally when only separated into their immediate constituents.

One of the most important agents in analysis is *heat* or *fire*, and even in some instances it is the only agent required. *Electricity* often appears to operate in analysis in nearly the same manner as fire. Thus ammonia is equally decomposed by the electric spark and by ignition; hydrogen and oxygen by both are united into water. In the Appendix we shall describe the kinds of APPARATUS particularly adapted to the most accurate analytical experiments. We may here enumerate, the burning lens for applying solar heat; the simple and elegant apparatus, consisting of a tube passed through a furnace, whereby substances are ignited without contact with the burning fuel; the electro-chemical apparatus; and the beautiful contrivance of Woulfe, for detaining separately the products of distillation, together with the pneumatic apparatus for gaseous substances.

The other great operation in analysis is the application of *reagents*, or substances which indicate the parts of the body to be examined, either by dissolving a portion if solid, or by separating a portion from its solution, if already in a liquid state, or by producing such changes of colour, smell or sensible properties, as are previously known to belong only to certain chemical compounds.

The particular precautions to be observed in the steps of chemical analysis differ so much, and the very mode of proceeding depends so entirely on the apparent nature and quality of the substance to be analysed, that it would be a fruitless task to collect under one head all that is to be said on this most extensive subject. We shall therefore refer the reader to the individual substance, as for example to *indigo*, where the methods of analyzing this dye are required, and also to the following articles.

The analysis of minerals, which has been more assiduously cultivated than perhaps any other branch of analytical chemistry, includes the examination of metallic ores, and of the other products of the mineral kingdom. But as the precise portion of metal sufficient to constitute a mineral a metallic ore, is unknown before analysis, and when known cannot be accurately laid down (the term *ore* being often used in a technical sense, to imply a proportion of metal worth the extraction in the large way); and as most minerals shew some trace of metalline ingredients, we shall refer the whole subject of the analysis of solid bodies belonging to the mineral kingdom to the article MINERALS, *Analysis of*.

The subject of *Mineral Waters* we shall treat separately.

The analysis of GASSES requires a peculiar apparatus and appropriate precautions.

The leading characters that distinguish ANIMAL and VEGETABLE matter will be enumerated under their respective heads, and may assist the practical chemist in determining to which of these great classes the substance which he is analysing may belong.

ANATASE. *Schorl-bleu* of R. De Lisle. *Oisanite* of Lametherie. *Octaedrite* of Saussure.

The colour of this mineral is for the most part steel-grey, which in certain directions passes into blackish or reddish-brown: it also occurs occasionally of a bright indigo-blue. It is found crystallized in lengthened octahedrons, the summits of which are sometimes truncated; the lateral faces are slightly striated across: the crystals are small, and often so minute that their form is scarcely to be recognized by the naked eye. The lustre of the anatase is very brilliant, between the metallic and vitreous: its fracture presents lamellæ, parallel to the four faces of the octahedron and to the base. It is commonly opaque, seldom translucent, very rarely semi-transparent. It is hard, brittle, difficult to break: specific gravity 3.85.

The anatase is not fusible, *per se*, before the blow-pipe: when heated with an equal weight of borax it fuses into a glass of an emerald green, which as it cools crystallizes in needles. By a further addition of borax, the result is a transparent glass of a hyacinth red: if this glass is heated gradually, at the extremity of the cone of flame produced by the blow-pipe, it becomes opaque and of a deep blue colour; by a continuance of the heat the blue changes to white, and in a higher temperature, the bright transparent hyacinthine colour again makes its appearance. These successive changes may be renewed at pleasure, as was first observed by M. Esmark.

The only substance with which the anatase is likely to be confounded is blende, but besides that the form and structure of these two substances are very different; it may be remarked that blende is incapable of scratching glass, which anatase will do very readily.

No accurate analysis of this mineral has yet been made; but Vauquelin has ascertained that its principal ingredient is oxyd of titanium.

The anatase is found at Vaujani, near Allevard, in Dauphiné, on the mountains near the town of Oisans. It lines the cavities of a vein that

traverses a primitive rock, and is accompanied by minute crystals of quartz and felspar.^a

ANIMAL MATTER. The antient division of terrestrial bodies into animal, vegetable, and mineral, applies with much more propriety to natural history than to chemistry: in the former science it furnishes a stable and useful basis for classification; in the latter it is at best ambiguous, and liable to mislead.

Several of the most important chemical elements are found sometimes in different, sometimes in the same combinations, in all the three kingdoms of nature, and therefore cannot with propriety be classified under any individual.

However, it is not unimportant to distinguish, as far as may readily be done, the *proximate* constituents of each natural class, and more frequent combinations which are met with by the chemist.

We may also observe here that almost all the discoveries relating to the chemistry of animal bodies are due to modern philosophers, and take their date from the period at which the analysis of gaseous bodies began to assume a regular scientific form. Many curious and valuable experiments are indeed to be met with before that period, and several interesting substances, such as phosphorus, prussic acid, ammonia, &c. were known to possess an animal origin; but the real nature of these bodies, the mode of their existence and their combinations, were yet undiscovered. An infinite labour yet remains in this department of chemistry, and the research is the more difficult as it demands the assistance of extensive knowledge in anatomy, physiology, and in the structure and the functions of animals; and as all the possible operations of the chemist, in his laboratory, appear to bear little if any analogy with those that occur in organized living bodies.

The present state of animal chemistry includes the analysis which has been made of the various animal solids and fluids; the chemico-physiological enquiries which have been instituted concerning the living functions; the changes produced by disease; those which take place after death; and several miscellaneous facts relating to the use of certain parts of animals in the arts, in medicine, &c.

Scarcely any arrangement will usefully include all the constituent parts of animal bodies, as in chemical properties they pass into each other by insensible gradations, and by apparently slight differences in the proportions of their elements. Still less will any arrangement, satisfactory to

the chemist, answer the purposes of physiology, or coincide with the distribution and mutual connexion of the animal functions. We shall content ourselves with enumerating the principal parts of animals, in the order which appears the most natural, and indicating the heads under which their chemical properties will be described.

The principal elementary solids of the body are the following; *muscle* or *flesh*, in which resides the power of motion, voluntary or involuntary, and in chemical properties differing from any other organ. *Cellular membrane* or *web*, (the *tela cellulosa* of physiologists,) a fine network, which forms the great connecting medium between the different organs, and answers an infinite variety of purposes of support, connexion and union: when condensed it forms the various *Membranes* or sheathings, *Tendons*, *Ligaments*, and on the surface of the body the true *Skin*. The chemical analysis of all these parts is considerably similar, regard being had to the age and nature of the animal, &c.—*Brain*, a peculiar chemical compound.—*Bone*, distinguished for the large proportion of earth and earthy salt; teeth, horn, and cartilage belong to this class.—The *Tegument* of animals, either for warmth or protection from external injury, to this belong the *Cuticle*, *Nail*, *Hair*, *Feather*, *Wool*, and many of the calcareous coverings or habitations of animals; *Shell*, *Coral*, &c. Some resemblance in chemical properties is found between the different kinds of soft and hard teguments respectively.

Of the animal fluids, the most important in every point of view is the *Blood*, that fluid from which every other part of the animal is formed, and which therefore must contain the elements of every thing animal that is met with. The analysis of this fluid is complicated and peculiar. The only substance approaching to it in properties appear to be the *Chyle*. *Milk* is unquestionably the next in interest, and its analysis has long been familiar to chemists. A great number of fluids might be termed *lymphatic*, or such as consist chiefly of water, holding in solution only a very minute portion of animal and saline matter. The *Perspiration*, the liquor which moistens the cavities of the body, the *Amnios*, the *Tears*, perhaps the *Saliva* and *Pancreatic Juice* are of this species. A more animalized lymph, distinguished by a greater degree of viscosity, is the *Mucus* of the nose, bronchia, the *Synovia*, &c.

The *Bile*, a species of animal soap much

^a Haüy traité de Min. vol. iii. p. 129. Mineralogie de Brochant. vol. ii. p. 548.

compounded, is a very peculiar fluid. *Animal Oil*, under the various names of *Fat*, *Tallow*, *Suet*, *Marrow*, &c. forms a distinct class. To this perhaps may be added, though considerably differing in chemical properties, *Wax* and *Spermaceti*. No animal fluid has occupied more attention than the *Urine*, even from the earliest times of animal chemistry.

Besides the foregoing substances, there are many others which have a place in the history of the analysis of animal matter, and cannot be easily arranged under any general head. Of this kind are musk, castor, ambergris, &c. which will be found under their respective titles.

The chief proximate constituent parts of the above-mentioned animal substances are: *Water*, which appears to enter simply as water into the composition of all the solids, to give flexibility and elasticity to the moving and yielding parts, and to form by far the greater part of all the fluids, oil excepted: *Fibrin*, also called *Gluten*, found in the blood, and the chief constituent of muscular flesh: *Albumen*, much resembling fibrin in chemical properties: *Gelatin* or *Jelly*: *Oil*: a species of *Resin*: one or two peculiar *Acids*: some alkaline and earthy salts, chiefly *Soda* and *Lime*, with the *phosphoric* and *muriatic* acids: and also a small portion of *Iron*.

The analysis of all kinds of animal matter presents a certain similarity of result which very satisfactorily coincides with the small number of elements into which the above proximate constituents are resolvable. It shews that Azot, Hydrogen, Oxygen, and Carbon, perform the leading parts in the innumerable changes by which every animal substance is elaborated in the living organs; but the disorganization of these by chemical means gives rise to certain compounds not to be found in the original body.

The analysis by fire was principally resorted to by the older chemists, and though less discriminative than the use of reagents, it is highly instructive. All the hard, the soft, and the fluid parts of animals (the latter being previously evaporated nearly to dryness) if put into a retort without addition, and heated first slowly and afterwards to ignition, exhibit nearly the following appearances:^a a watery fluid first clear, afterwards brown and turbid, distills over: this contains some ammoniacal salts, and soon after *carbonat of ammonia* comes over, part of which dissolves in the liquor, and part crystallizes on the neck and sides of the receiver. To this succeeds an oil, at first nearly limpid, but soon

coloured, thick and foetid. This oil is accompanied with more carbonat of ammonia partly crystalline, in part dissolved in the oily vapour. At the same time a quantity, often very large, of gas passes over, which is found to be chiefly carbonic acid, but foetid on account of its mixture with the empyreumatic oil, and mixed with carburetted hydrogen, and sometimes sulphuretted or phosphuretted hydrogen. When nothing more is given over, and the retort is red hot, if the process is stopped, a shining black coal is found, very difficult to burn to ashes, and mixed with the phosphat of lime, and other fixed matter which the substance contained. The chief products therefore of animal matter distilled without addition, are water, carbonat of ammonia, animal oil, carbonic acid gas, and a residue of coal with fixed earthy salts. But of these products scarcely one is found in this precise combination in the animal substance before distillation; they are therefore *formed* out of their elements by the action of fire, and hence the confusion and uncertainty attending the analysis of these bodies before the nature of water, of carbonic acid, of ammonia, and of hydrogen, was understood. Of these products, the volatile alkali is the most important, for it is generated in abundance by many changes to which animal bodies are exposed, and is not to be detected except in minute quantities, before these changes have taken place. In the article ammonia, we have fully shewn the composition of this alkali to be azot and hydrogen, and hence it becomes requisite in accounting for the generation of ammonia, to prove the existence of its two constituent elements in animal matter. The presence of hydrogen is obvious, from the quantity of water existing in all animal substances, from the production of oil by distillation, and the actual evolution of much hydrogen in a gaseous form, mixed with carbonic acid. The presence of the azot has been demonstrated in an equally satisfactory and very ingenious manner, especially by the valuable researches of M. Berthollet.

This admirable chemist resorted to the nitric acid as an agent for the decomposition of animal matter. He found that when silk, hair, wool, and other animal substances were digested with nitric acid *with application of heat*, a peculiar oily substance was produced, and along with it a large quantity of *Oxalic acid*,^b the particulars of which experiments will be described under this acid. In a subsequent series of experiments,^c the same chemist, pursuing the

^a Fourcroy Syst. de Conn. Chem.

^b Mém. de l'Acad. des Sciences, 1780.

^c Ibid. 1785.

former subject in connection with the composition of ammonia, which then engaged his attention, treated a given portion of silk with nitrous acid as before, but with an apparatus for collecting the gasses that might be produced. He found (as indeed Dr. Priestley had done before) that the first effect of the acid *before the application of heat*, was to disengage a very large portion of *azotic gas*. After this, on heating the mixture, much nitrous gas was generated, and oxalic acid was *now* produced. There are therefore two periods of the operation of nitrous acid on animal matter, the first, without heat, characterized chiefly by the production of azotic gas; the latter with heat, distinguished by the production of oxalic acid and other phenomena, which will be elsewhere noticed. After the first period it is also found that the nitric acid itself is not decomposed, as it will saturate as much alkali as before: consequently the azot must be generated from the animal substance.

Though the presence of azot in animal matter cannot be questioned, we possess no other means of extracting it perfectly in its insulated form except the one above mentioned, for the elements of animal substances appear to be peculiarly liable to combination, and among them the azot. The generation of nitric acid is another azotic combination, animal matter being requisite for the manufacture of saltpetre. The relative quantity of azot contained in different animal matters, is therefore in general to be inferred from that of the ammonia which it produces by distillation, or by other processes of decomposition, and subsequent experiments with nitric acid, confirm this position.

PUTREFACTION, or the spontaneous analysis of animal matter, performed by warmth and moisture, though a most repulsive process to all the senses, has engaged the attention of several excellent chemists, and the phenomena which it exhibits illustrate in a striking manner the other analytical experiments. Under this article it will be seen how important are the combinations of azot in this natural process, and how intimately it is connected with the production of ammonia and of nitric acid.

The action of heat and of acids under certain circumstances also generates the *PRUSSIC Acid*, a substance peculiarly animal and worthy of attention.

The operation of the nitric acid on animal matter has already been mentioned; the sulphuric acid acts with almost equal energy but in a somewhat different manner.⁴ A piece of

flesh, for example, immersed in this acid, concentrated, but cold, soon becomes coloured successively yellow, red, and black, and acquires a pasty consistence: the mixture heats, but gives out no gas, and when examined the acid is found diluted with the water extracted from the flesh, and also in part saturated with ammonia and soda. The flesh is charred, and there separates from it a portion of oily matter. The precise nature of the change is not entirely understood, but the generation of ammonia is indisputable, as this alkali is found in union with the acid, and could not be previously detected in the animal matter. Another singular production also in this case is, the acetous acid, which may be detected by diluting the mixture, filtrating and distilling the liquor. The acetous acid rises in the distillation.

The caustic fixed alkalies have long been known to act most powerfully upon animal matter: when concentrated and especially assisted by heat, they dissolve indiscriminately all the soft parts into a saponaceous pulp. M. Fourcroy has found that ammonia is disengaged at the time of its action, and that it is *formed* in the process. See SOAP, *Animal*.

So much remains to be done on the subject of animal chemistry, that it might be superfluous to enlarge further on a general head. The collective industry of chemists however, presents a very respectable mass of information concerning the properties of a variety of the most interesting substances belonging to this great class of natural bodies, to which individually we shall refer our readers.

ANNEAL. When a substance melted or nearly in a state of fusion, is cooled very hastily, its texture is so much altered, that, if a ductile metal, it loses much of its malleability, and cannot be extended far under the hammer without cracking; or, if a brittle metal, a glass, or vitrescent mixture, it is liable to fly to pieces by a very slight change of temperature or external injury. To avoid this the process of annealing is resorted to, which is nothing more than cooling the heated or melted substance as slowly and equally as possible, often in a separate furnace of the requisite heat, and sometimes called an *annealing oven*. The utility of annealing is shewn very conspicuously in the manufacture of *Glass*, the casting of *Speculum Metal*, or the beating of *Gold*.

ANNOTTA, or *Arnotta*. Roucou, Fr. Orlean. Germ.

Arnotta is a dry hard paste, brownish on the

⁴ Fourcroy.

outside and red within, brought from Cayenne and various other parts of America, in long rolls of about two or three pounds weight, and much used in Europe in dyeing. This article is procured from the seeds of a large tree, the *Bixa Orleana* of Linnæus, *Roucouer*, or *Macaw* tree, also called by the Caribs *Achiote*, *Cochebue*, or *Bichet*, and by the Brazilians, *Urucu*. They are thus prepared; the seeds when ripe are gathered, the husk taken off, gently bruized and put into a trough to soak for about eight or ten days, being well stirred twice a day with a wooden implement. They are then beaten with heavy mallets for a quarter of an hour, till they are thoroughly bruised, again moistened with water and passed through a sieve. When thus reduced to a kind of pulp, it is put into a wooden vat, and allowed to ferment or putrify for a week, during which time it gives out a very fetid smell, and moulds on the surface. After this the pulp is again beaten, and soaked with water twice successively.

The seed is now nearly exhausted of its colouring matter, which has passed into the several waters with which it has been washed, and which are carefully reserved, strained through sieves, and mixed in different proportions. This water holding the colouring matter suspended, is then transferred into iron boilers, and heated gradually, till a scum rises to the surface, which is successively removed as it forms into another boiler. This scum is the annotta, and it is slowly dried in the last boiler with perpetual stirring, till it is of so thick a consistence as not to stick to the wetted finger. After this it is laid out on the floor to dry, and made up into cakes, (the negro who does this part of the business smearing his hands with palm oil,) and finally wrapped up in palm leaves, and in two months time it is fit for exportation.

The Caribs make annotta in a much simpler manner. They take the seeds when ripe, and rub them for a long time in their hands smeared with palm oil, till the fine red outer coat of the seed is rubbed off and sticks to the palm of the hand, which is the annotta, and undergoes no other preparation than being moulded into large cakes and dried. This is esteemed the purest, as it has undergone no change by fermentation.

Annotta readily dissolves in water, and more easily in alcohol. Its solutions have a yellowish red, or orange cast. The watery decoction has a strong smell, and an unpleasant rather pun-

gent taste. Alkalies change it to a high orange, and much assist the solution in water. Acids precipitate from the solution an orange sediment, soluble in alkalies. Alum gives a similar precipitate or lake, but of a deeper hue. Sulphat of iron gives an orange brown lake; sulphat of copper a yellowish brown; solutions of tin a lemon coloured.

Annotta is employed in the countries where it grows for various purposes of colouring, for staining the skin, giving a colour and a peculiar taste to certain articles of food, sometimes to chocolate. In Europe it is used largely in dyeing, particularly silks, of different hues of red, orange, aurora, &c. In this case it is always prepared with an alkali, which gives a cast of red. The colour is fugitive, particularly in the sun's light, but it is not readily washed out, and is a very powerful dye, a small quantity giving a tinge to a very large body of liquor.^a

A peculiar use of annotta is in giving the high orange yellow to Cheshire and Wiltshire cheese, so much in fashion at present. To employ it, the annotta is rubbed on a stone with a little whey, till a sufficiently strong solution is made, which is mixed with the cheese-curd just before pressure.

ANTS, *Acid of*. See FORMIC ACID.

ANTIMONY. *Στιμμι*, Gr. *Stibium*, Lat. *Spießglas*, *Spießglanz*, Germ. *Antimoine*, Fr. *Proteus*, *Leo ruber*, *Plumbum nigrum*, *Balneum regis*, *Lupus metallorum*, Alchem.

Antimony is a compact brittle metal, of a brilliant slightly bluish-white colour; fusible at a red heat, and by a higher temperature, with exposure to air, wholly convertible into a white vapour. It is soluble in nitro-muriatic acid; and precipitable therefrom in the form of a white powder by distilled water, and of a deep brick red colour by liquid hydrosulphuret of ammonia.

Antimony is found in occasional mixture with the ores of lead, of copper, and of silver; but the six following are the only species which are allowed by mineralogists to rank as the proper ores of this metal.^b

Sp. I. Native Antimony; *Gediegen Spießglas*; *Antimoine natif arsenifere* (of Haüy)

The fresh-broken surface of native antimony is of a pure tin-white colour, but by exposure to the air it acquires a slightly greyish or yellowish tinge. It is found in mass, disseminated and kidney-shaped. Its lustre is metallic, very

^a Berthollet's Art of Dying. Encycl. Method. Arts and Mets. (Art. Roucou.) Leonhardi Wort. (Art. Orlean. &c.)
^b Brochant Mineralog. vol. ii. p. 369. Haüy Traité de Mineralog. vol. iv. p. 252. Emmerling, vol. ii. Weidemann, Handbuch, &c. De Lile Crystallographie, vol. iii. Kirwan's Mineralogy, vol. ii.

brilliant, even specular. It is composed of flat or slightly curved plates, and therefore presents a foliated fracture. It is brittle, and moderately hard, passing into tender: its specific gravity has not been ascertained, but is considerable, probably about 6.0.

Antimony when native is by no means in a state of absolute purity, but always contains a portion of arsenic, varying from two to fifteen per cent. hence it exhales an alliaceous odour when heated before the blow-pipe.

Native antimony was first discovered in 1748, at Sahlberg, in Sweden, by Schwabe, in a gangue of white calcareous spar; and has since been found at Allemont, in Dauphiné, by Schreiber, in white quartz. It may be considered, however, as a very rare mineral. Arsenical silver having a general resemblance to native antimony, has sometimes been mistaken for it; a minute portion, however, exposed to the blow-pipe, at once shows the difference, the latter being wholly evaporable, while the former, after giving out a little arsenical vapour, remains behind, forming a bead of silver. The native tellurium of Fatzebay has also a considerable resemblance to native antimony, but its colour is not quite so white, and before the blow-pipe it decrepitates and volatilizes with a clear somewhat brownish flame.

Sp. II. Grey Sulphuret of Antimony; *Grau Spießglas-erz*; *Antimoine Sulphuré*. (Haüy.)

This species is divided by the German mineralogists into four varieties, the compact, foliated, radiated and plumose.

Var. 1. Compact.

The colour of this substance is lead grey, passing into steel grey, and tarnishing blue or purple by exposure to the air. It occurs in mass or disseminated. Its lustre is metallic, shining or little-shining. Its fracture is small grained, uneven. It is tender, easily broken, leaves a greyish trace when rubbed on paper, and by this means acquires a polish. Its specific gravity is considerable, but has not been exactly ascertained. When exposed to the blowpipe it melts very easily, giving out a white vapour and a sulphureous odour: by a continuance of the heat it is entirely volatilizable. So great is its fusibility that it will flow when held for a short time in the flame of a candle.

This variety is rarer than any of the following. It is found mixed with other antimonial ores at Braunsdorf, in Saxony; Goldkronach, in Bareith; Majurka, in Hungary; and in Auvergne: it is usually accompanied by quartz and spathose iron ore.

Var. 2. Foliated.

This variety differs from the preceding in being of a high steel-grey colour, and in presenting a fine grained foliated fracture. Specific gravity 4.36. It is almost always accompanied by quartz, and by the two following varieties. It is found at Gold-kronach, Braunsdorf, Stolberg, in the Hartz and Nagyag in Transylvania.

Var. 3. Radiated. (Striated, of Kirwan.)

The recent fracture of this mineral is, like the preceding, of a light steel-grey colour; its surface, however, presents a blackish grey colour, mixed with azure blue, golden yellow, and other iridescent tints. It occurs in mamillated, glandular, and stalactitic masses, or disseminated, or crystallized. The primitive crystalline form of sulphuretted antimony has not yet been ascertained; it is, however, easily and very neatly divisible by sections made parallel to the axes of its prisms. The only regular crystals of this mineral are, 1. An oblique angled tetrahedral prism, terminated by tetrahedral pyramids, with triangular faces, (*Antim: sulphuré quadrioctonal* of Haüy.) 2. The same prisms, bevelled at the acute-angled edges, and terminated by tetrahedral pyramids with trapezoidal faces, (*A. S. sexoctonal* of Haüy.) It also occurs in bundled or diverging needles, or in obscure cylindroids. The surface of the crystals is always striated longitudinally, and is commonly of a very brilliant metallic lustre. The internal lustre is sometimes much, sometimes little-shining. The fracture is striated, either broad or narrow; radiated, diverging or implicated: when the striæ are very broad, they give almost a foliated appearance, and being very brilliant, such specimens have obtained the name of *Specular Antimony*. It flies, when broken, into irregular prismatic or long-granular fragments; is tender and somewhat brittle. Sp. grav. from 4.13 to 4.51. According to the analysis of Bergman, it consists of 74 antimony and 26 sulphur, *per cent*. The Hungarian antimony also contains a variable proportion of gold.

This variety is the commonest of all the antimonial ores. It is procured in Hungary, at Felsőbanya, and Kremnitz; at Dravitz, in the Bannat; at Braunsdorf and Rochlitz, in Saxony; at Lubillac, in Auvergne, and at Allemont, in Dauphiné, in France; at Pereta, in Tuscany; in Cornwall, in England; also in Spain, Mexico, and Siberia. The most splendid iridescent specimens come principally from Hungary and Auvergne.

It is found for the most part in micaceous schistus and clay porphyry, mixed with pyrites.

and oxyds of iron. Its gangue in Hungary is sulphated barytes, but elsewhere quartz; or, rarely, calcareous spar, fluor spar, or chalcedony.

Var. 4. Plumose. (*Federerz: Antim. sulph. argifentifere* of Haüy.)

Its colour is steel-grey, passing into greyish black, lead or smoky-grey; by exposure to the air it tarnishes to an iridescent blue or yellow. It occurs in minute capillary crystals, investing the surface of other minerals with a delicate down or wool; the crystals are often scarcely visible to the naked eye, and so interlaced as to appear like an amorphous crust. The external lustre of this mineral is semi-metallic, little-shining. Its fracture is confusedly fibrous. It is very tender, almost friable. Sp. grav. 3.57.

Before the blowpipe it emits a smoky that deposits a white and yellow powder on the charcoal, and the residuum melts into a black slag. It has not yet been accurately analysed, but according to Bergman consists of antimony, iron, arsenic, sulphur, and sometimes silver. The proportion of the last ingredient is very variable, never exceeding 4 per cent. it is therefore improperly ranked by some mineralogists among the silver ores.

It is upon the whole a mineral of rare occurrence, and is found chiefly at Freyberg and Braunfsdorf, in Saxony; and at Stollberg, in the Hartz; also at Schemnitz, in Hungary. It is accompanied by quartz, calcareous spar, brown spar, galena, martial pyrites, and blende.

Sp. III. Red Antimony. *Roth Spiesglas erz. Antimoine hydrofulpuré* of Haüy.

The colour of this mineral is a cherry red, more or less deep, passing on the surface into brown, reddish, or bluish. It occurs sometimes massive or disseminated, but most commonly in minute capillary crystals, either radiating or implicated. Its lustre is little shining, vitreous; its fracture is fine and irregularly fibrous. It is opaque, brittle, almost friable: sp. grav. 4 to 4.7.

It melts easily before the blowpipe and evaporates, giving out at the same time a feeble sulphureous odour. Red antimony has sometimes been confounded with the red silky oxyd of copper: this latter, however, is of a brighter red colour, and dissolves with effervescence in nitrous acid, communicating to the solution a green tinge; the antimonial ore, on the contrary, is insoluble in nitrous acid, and by the action of this fluid is covered superficially with a white crust. No accurate analysis has yet been made of this mineral: it was formerly supposed, on account of its colour, to contain arsenic and sulphuretted antimony; according

to Sage it is a native kermes, or hydrofulphuret of antimony: thus much, however, is certain, that it occurs in the crevices and investing the surface of the common grey fulphuret of antimony, and appears to originate from this by the process of spontaneous decomposition: the amorphous or massive variety is frequently studded with octahedrons of native sulphur.

It is found at Braunfsdorf, in Saxony; Malazka and Kremnitz, in Hungary; and Allemont, in Dauphiné.

Sp. IV. White Antimony. Muriated A. of Kirwan; *Weiss Spiesglas erz; Antimoine oxydé* of Haüy.

The colour of this mineral varies from snow-white or yellowish white to greyish and ash-grey. It is found rarely in mass; more frequently in the form of stars or diverging needles, upon the surface of other substances; also crystallized, in the form of tables, with four rectangular faces, or cubes, or tetrahedral prisms, which are accumulated together in bundles or cells. The surface of the crystals is smooth, or longitudinally striated and very brilliant. The fracture is stratified, exhibiting a bright vitreous lustre, passing into the pearly. It is translucent, brittle, tender and heavy.

In entire crystals it decrepitates before the blowpipe, but when pulverized it melts quietly and without difficulty, giving out a white vapour, and by degrees entirely evaporates. Between two coals it may be reduced to the metallic state. The tabular crystals, according to Klaproth, are composed of oxyd of antimony with muriatic acid. The needle-shaped variety from Dauphiné, has been analysed by Vauquelin, and appears to contain

86 oxyd of antimony,
3 oxyd of iron and oxyd of antimony,
8 filix,

97

3 loss

100

White Antimony is an extremely rare mineral: the tabular kind is principally found at Przibram, in Bohemia, on the surface of galena; the fibrous variety comes from the mountain Chalanques, near Allemont, in Dauphiné. It is probable, however, that two distinct species are confounded together under the appellation White Antimony; the one being muriat of Antimony in tabular crystals, from Bohemia; the other being oxyd of Antimony, in bundled fibres, from Allemont.

Sp. V. Antimonial Ochre; *Spiegelglas okker*; *L'ochre d'Antimoine* of Brochant.

The colour of this substance is straw or lemon yellow, passing to yellowish grey. It occurs in mass, disseminated, or investing; it is without lustre, has a fine earthy fracture, is soft, heavy, and brittle.

Before the blowpipe it becomes white, and volatilizes without melting; it effervesces when fused with borax, and is in part reduced to the metallic state. It has not yet been analysed, but is supposed by Karsten to be an oxyd of Antimony. It occurs in small quantities at Braunfsdorf, in Saxony, and in Hungary, mixed with grey and red Antimony.

Sp. VI. Yellow Antimony; *Gelb spiegelglas erz*; *La mine d'Antimoine jaune* of Brochant.

The colour of this mineral is orange or wax-yellow, or yellowish white, often becoming dusky by exposure to the air. It is found crystallized in striated interlaced needle-shaped prisms, or in quadrilateral tables: it is shining, and, when black, possesses a metallic lustre; it is soft, flexible, and heavy.

Before the blowpipe it melts without much difficulty into a dark-grey friable slag, containing a small grain of metal. It is not volatilizable, neither does it inflame. This substance has not been analysed, and it rests on the sole authority of Count Rafumousky and Baron Born; the former of whom found it in a vein of grey sulphuretted Antimony at Faucigny, in Savoy; it has also been found at Malazka, in Hungary. By Rafumousky it is considered as a phosphat of Antimony, whereas Born supposed it to be a combination of the muriats of antimony and lead.

We are as yet but very imperfectly acquainted with the composition of most of the antimonial ores; it is impossible, therefore, to give a very correct method of performing this analysis.^a The native antimony, being an alloy of antimony and arsenic, is best decomposed by solution in nitro-muriatic acid and precipitation by pure water. For this purpose reduce the ore to fine powder, and digest it, at a moderate heat, in an acid composed of nitric acid, sp. gr. 1.25 one part, strong muriatic acid, three parts; in this, both the antimony and arsenic will be dissolved, and the addition of pure water will precipitate the antimony, leaving the arsenic in solution. The analysis of this ore may likewise be effected, perhaps with superior accuracy, by digestion in strong boiling nitric acid, which will acidify and dissolve the arsenic, leaving the antimony behind

in the state of white oxyd, which may afterwards be dissolved by nitro-muriatic acid, and precipitated by water.

The grey sulphurets of antimony, when not crystallized, are seldom perfectly pure, but contain in combination or intimate mixture, iron, lead, copper, and silver; to which must be added the earths composing the stony gangue, from which they cannot be perfectly separated previously to analysis. With these compound ores the best method of proceeding is to take (a) 500 grains, finely pulverized, and digest it with 1500 grains of pure nitric acid, sp. gr. 1.25 and 1000 grains of water for about half an hour, at the temperature of 150° Fahr. then pour in a quantity of pure water equal to the rest of the fluid, mix the whole well together, and pour off the liquor as soon as it becomes clear; it will consist of the nitrats of silver, lead, and copper, with probably a little iron, dissolved in an excess of acid. The iron may now be separated in the state of red oxyd by simple boiling, and subsequent filtration. Then (b) drop muriat of soda into the solution, as long as any precipitate takes place, and allow the whole to stand till the supernatant fluid becomes perfectly clear; the precipitate is pure muriat of silver, which, being separated and washed, may be mixed with two or three times its weight of dry pearlash, and reduced by fusion to the metallic state.

(c) The solution (b) must now be saturated by potash or soda, and concentrated by evaporation to about one-third of its bulk; caustic ammonia, in excess, being then added, the lead will be precipitated as white oxyd, and the copper will remain in solution. The lead, by fusion with black flux, will be reduced to the metallic state.

(d) The solution (c) is, lastly, to be slightly acidulated with nitrous acid, from which carbonate of potash will throw down the green oxyd of copper, and this may be brought by a low red heat to the state of brown oxyd, 100 parts of which denote 85 of metal.

(e) The portion of ore insoluble in the process (a) is to be digested, at a temperature somewhat inferior to boiling with successive portions of nitro-muriatic acid (consisting of nitric acid sp. gr. 1.25 one part, strong muriatic acid three parts) as long as any thing is taken up; the solutions being then mixed and concentrated by evaporation, are to be poured into a considerable quantity of pure water; an immediate precipitate of white oxyd of antimony will take place, which, being separated and washed, and

^a Bergman's Ess. Klaproth's Analyt. Ess. Kirwan's Mineralogy, vol. ii.

mixed with twice its weight of crude tartar, and a little nitre, is easily reduced by a full red heat continued for a few minutes to a metallic button.

(f) The solution (d) contains now only a little sulphuric acid and iron, with some earthy matter. The addition of nitrat of barytes, as long as any precipitate falls down, indicates the quantity of sulphur; after which, an excess of caustic potash, assisted by a boiling heat, will throw down the iron, and retain the alumine and filix.

(g) The insoluble residue of process (d) containing only sulphur and earth, is decomposed by ignition, the sulphur flying off, and the earth remaining.

Thus the quantity of antimony is obtained by process (e);

of sulphur and earth by (f) and (g);

of iron by (a) and (f);

of silver by (b);

of lead by (c);

of copper by (d).

The grey sulphuret of antimony is the only ore of this metal which is found in sufficient quantity for the purposes of commerce, and it is fitted for market in the large way by simple fusion.^b For this purpose the ore being dressed and separated from the greater part of its stony gangue by hand, is placed in the bed of a reverberatory furnace, and covered with charcoal powder; being then brought to a low red heat, the sulphuret of antimony enters into fusion, while the earthy parts float on the surface, and are taken off with a rake or ladle; the fluid portion is then cast into the form of loaves or large cakes, and is fit for sale, forming the *common* or *crude* antimony of the shops. The old method of obtaining crude antimony, and which is still practised in some of the French founderies, was by means of an apparatus consisting of a large crucible, the bottom of which was perforated, and inserted into the wide end of a conical tube, passing through the furnace, and terminating in an earthen pot or reservoir. The crucible was filled with ore broken into small pieces, a cover was luted on, and by the application of a moderate heat, the liquefied antimony dropped through the tube into the reservoir below, while the stony parts were detained in the crucible.

From the crude or sulphuretted antimony thus prepared, there are several methods of separating the sulphur, and procuring the metal in a state of purity; the best, and which is the

most used in processes in the great way, is the following.

Reduce the sulphuret to small pieces, and strew it evenly and thinly on the floor of a reverberatory furnace, in order to drive off the sulphur by roasting. The heat at first must be very gentle, scarcely exceeding that required for the fusion of tin, otherwise the antimony will clog or even melt: in a short time a lam-bent blue flame, proceeding from the combustion of the sulphur, will appear over the surface of the ore, which, at the same time, will begin to lose its metallic lustre, and be converted into a greyish oxyd. By assiduously stirring the ore, and cautiously increasing the temperature as its fusibility decreases, it will, in the course of some hours, cease to emit sulphureous vapours, and bear a moderate red heat without melting. The roasting is now finished, and when the ore is removed from the fire, and becomes cool, it will be found converted into an ash-grey oxyd, weighing from thirty to thirty-six per cent. less than the original sulphuret, and still by no means entirely free from sulphur. In order to obtain the regulus from this grey oxyd, it is to be mixed with half its weight of crude tartar, and exposed to a full red heat in a covered crucible. The carbonaceous part of the tartar decomposes the oxyd, and the antimony, reduced to the metallic form, collects itself in a mass at the bottom of the crucible, except a variable proportion, which is held in solution by the sulphuret of potash formed by the alkaline base of the tartar and the sulphur of the oxyd. The quantity of metal thus obtained in the large way, equals from 66 to 70 per cent. of the oxyd employed; but a much greater loss will be observed, if the ore has not been properly roasted. The method followed by T. Kunkel appears, however, on the whole, to be better and more economical than the common practice. He mixes the roasted oxyd with oil or fat, and a little powdered charcoal, puts the mass into a crucible to melt, and as soon as the regulus begins to show itself, injects, by degrees, some powdered nitre, in the proportion of an ounce to a pound of oxyd: the matter soon appears in thin fusion, and on being poured out affords a pure regulus, in considerably greater proportion than is obtainable by the usual way of operating.

The expence of nitre and tartar in preparing regulus of antimony in large quantities, for the purpose of commerce, is very considerable, in consequence of which a series of experiments were undertaken by Hassenfratz, Vauquelin,

and Bouillon la Grange,^c in order to ascertain whether the use of these substances could be superseded by cheaper materials. In the prosecution of this enquiry, different portions of the roasted ore were mixed with charcoal powder, with tallow, and with pitch, and exposed in covered crucibles to a heat sufficient for their reduction: the crucibles being then withdrawn were found to contain only a little carbonaceous matter, and a few minute globules of antimony, all the rest being evaporated. Some grey oxyd was then mixed with 1st. two parts of lime and one of clay; 2d. equal parts of sulphat of barytes, chalk and clay; 3d. with common salt; 4th. with sulphat of soda: and the materials being strongly heated, were all found converted into yellow glasses, without any appearance of regulus. These being each pulverized, and mixed with charcoal powder, were again heated as before, and produced only vitreous scorixæ, with a few minute globules of antimony. Lastly, some of the same grey oxyd being fluxed with half its weight of tartar, yielded a perfect button of pure antimony. Hence it appears that potash (and probably the fixed alkalies in general,) exert some specific action on antimonial oxyd, which renders it much more fixed while converting into regulus, than when mere carbonaceous or even vitrescent fluxes are made use of.

The most expeditious, though at the same time the most expensive and inaccurate manner of procuring the regulus of antimony, is by *scorification*. For this purpose eight parts of the grey sulphuret are reduced to a fine powder, and mingled with six parts of tartar and three of nitre. The mixture is projected gradually into a red hot crucible, till it is nearly filled, a slight detonation taking place at each successive projection: the crucible is now closed with its cover, and a brisk heat being applied for nearly half an hour, the contents are either suffered to cool in the crucible or are poured into a greased and heated iron cone. The upper part of the mass consists of alkaline scorixæ, holding in solution a portion of antimonial oxyd, beneath which is a button of pure antimony, weighing between three and four eighths of the original sulphuret. Some advise that the nitre and tartar should be detonated together before the crude antimony is added; but this is decidedly an injudicious way of proceeding, the use of the nitre being not to alkalize the tartar but to oxygenate the sulphur; hence it is probable that the yield of regulus would be increased by first detonating

together the nitre and sulphuret, and not adding the tartar till towards the end of the process.

An excess of nitre or tartar, or both, is carefully to be avoided, as it not only enhances the expence but diminishes the produce. Lemery^d found that sixteen ounces of sulphuretted antimony, mixed with an equal weight of nitre, and the same of tartar, yielded only five ounces and a half of regulus; whereas sixteen ounces of sulphuret, twelve ounces of tartar, and six ounces of nitre, afforded six ounces and one dram of regulus.

There is yet another way of separating the regulus of antimony from the sulphur with which it is naturally combined, by taking advantage of the superior affinity for sulphur which other metals possess over antimony. There are five metallic substances capable of decomposing crude antimony with greater or less accuracy, by being fused together with it; these are iron, copper, lead, silver, and tin; only the former is at present, however, made use of, as it is both cheaper and more effectual than any of the rest. The antimony procured by this method was called by the old chemists *Martial regulus*, on account of the use of iron in its preparation, a name which may very properly be retained, as it is impossible by any other means than solution in acids to render this regulus absolutely free from iron: in strictness, therefore, it ought to be considered as antimony alloyed with a small and variable proportion of iron. In order to prepare the martial regulus as free from iron as possible, the following method, recommended by Lemery and Beaumé,^e appears upon the whole to be the best. Take eight ounces of horse-shoe nails, and heat them in a crucible almost to whiteness; then add sixteen ounces of coarsely pounded crude antimony; cover the crucible and keep up the fire; in a few minutes the whole will be melted; at which time add by degrees three ounces of nitre: after a slight detonation has taken place, and the whole is brought to a state of perfect fusion, pour it into an iron cone, previously heated and greased, and strike the sides of it gently as the mass becomes solid, to favour the precipitation of the regulus. When cold it will be found to consist of a mass of antimony, weighing about ten ounces, covered by an alkaline ferruginous scoria, from which it may be readily separated by a blow with a hammer. The regulus, however, still contains not only iron but sulphur; it must therefore be remelted, and two ounces of crude antimony, and three ounces of nitre are then to be added;

^c Ann. de Chim.

^d Sur l'Antimoine.

^e Lemery sur l'Antimoine. Beaumé Chimie expérimentale.

when all detonation has ceased, pour it into a cone as before, and separate the regulus from the scorix. Remelt the regulus, and project upon it three ounces of nitre, then separate this purified regulus from the scorix, and once more melt it with a strong and rapid heat; project upon it, by degrees, three ounces of nitre, and immediately after pour it into a cone: there will be obtained about eight ounces of a beautiful stellated regulus, covered with yellowish white scorix. In this process the materials employed are, eighteen ounces of sulphuret, eight ounces of nails, and twelve ounces of nitre; four separate fusions are required, and the product is eight ounces of regulus.

The martial regulus may be procured in a more expeditious way, though not so free from iron, by bringing five ounces of horse-shoe nails to a white heat in a crucible, and then adding sixteen ounces of crude antimony: as soon as the whole is in very liquid fusion, project, at several times, one ounce of pulverized nitre; when the detonation has entirely ceased, put on the cover of the crucible, raise the heat for a few minutes, then remove the crucible from the furnace, and allow it to cool very gradually; there will be found beneath the scorix about seven ounces of regulus.

Perfectly pure antimony, whether procured by roasting or scorification, is a metal of a dusky white colour, between that of tin and iron, and exhibits, when recently broken, a remarkable degree of brilliancy: it is entirely destitute of ductility, and may, without much difficulty, be reduced by trituration to a fine powder; it is moderately hard, yielding easily to a common knife: its fusibility is rather less than that of zinc, as it requires a low red heat to be kept in a liquid state. Its specific gravity, according to Bergman, is 6.86; but by the experiments of Brissot, amounts only to 6.702. Its fracture is generally broad-foliated, but sometimes the facets are so minute as to give it almost a granular appearance: the magnitude of the plates of which it is composed, depends for the most part on the slowness with which it is cooled. The primitive crystalline form of antimony has not yet been ascertained; Haüy has found that it is divisible, at the same time parallel to the faces of a regular octahedron, and of a rhomboidal dodecahedron. If a large crucible is filled with melted antimony, and allowed to cool very gradually, and if, as soon as a crust has formed on the surface, the fluid beneath is poured out, by inclining the vessel and breaking a small hole

in the crust, the hollow will be found studded with various crystalline groups, consisting of cubes, of lengthened rectangular parallelepipeds, and of ramifications made up of small octahedrons, implanted into each other, or aggregated into a furrowed trihedral pyramid. The strong tendency of antimony to assume a crystalline form, is also shewn by the appearance of a radiated star, or pinnated leaves, like those of fern, with which the surface of pure antimony that is not cooled too hastily is generally covered: this will not take place except the metal is pure or nearly so, hence the term *stellated* is nearly synonymous with purified, regulus. By the alchemists this star was considered as a mysterious guide to the true method of making gold, which accounts for the vast number of alchemical processes that are recorded relative to this metal.

Antimony is but very little disposed to be acted on by air and moisture, at any degree of the atmospheric temperature; after a considerable time, however, it is deprived of its lustre, and covered with an extremely thin coat of firmly adhering black oxyd. By a low red heat, and free contact with the air, it may be entirely converted to a whitish grey oxyd, which at a higher temperature is volatilizable, and capable of being more highly oxygenated. When the metal is made to boil by the application of an almost white heat, and then exposed to a current of air, it is rapidly converted into a white vapour, which condenses as it cools into brilliant crystalline needles, of a snowy or silvery white, which have obtained the name of *argentine flowers* of antimony, or *snow of reguline antimony*. In order to prepare this oxyd in perfection, and with economy, the best method is^c to place a wide cylindrical earthenware tube, closed up at one end, in a wind furnace, so that it shall remain in a slanting direction, with the mouth projecting a little way through a door, or hole in the side of the furnace; and to prevent the inside of the tube from being too much cooled, an earthen-ware stopper must be fitted loosely into the open mouth of the tube: when the bottom of this vessel is red hot, introduce the antimony in small pieces, and close the aperture with the stopper. After the metal is melted, it will begin to smoke, and the oxyd will be deposited in slender crystals upon the sides of the tube, whence it may be scraped off from time to time with a clean iron spoon. The first crystals are often of a yellowish colour, perhaps on account of a small portion of sulphur

^c Beaumé Chimie expérimentale.

yet remaining in the antimony, those that succeed, however, are of a brilliant silvery white, without the smallest tinge of any other colour. The crystalline oxyd is a pure saturated combination of antimony and oxygen, in the proportion of eighty of the former to twenty of the latter, according to the analysis of Thenard.* In many of its properties it resembles the metallic acids: it is sparingly soluble in water, has a decided taste, combines with the alkalies into crystallizable salts, and may be again separated by the action of any of the more powerful mineral acids. When heated by itself in a close vessel, it is converted by the first impression of the fire into a yellow oxyd, and afterwards runs down into a yellow glass, containing 19 *per cent.* of oxygen; as the heat increases it assumes a reddish brown tint, and approaches nearer and nearer to the metallic state, till it is finally converted into black oxyd, holding no more than 2 *per cent.* of oxygen. The argentine flowers, by hasty fusion in a crucible, are converted into a vitreous mass, which when transparent is of a yellowish orange colour, and has obtained the name of *glass of antimony*, and when opaque is of a brown colour, and is called *liver of antimony*: these preparations are now, however, entirely obsolete, the common glass and liver of antimony being at present prepared from the sulphuretted oxyd.

We now come to consider the action of acids upon reguline antimony.

The *Sulphuric acid*, when cold, has little or no action upon this metal; but when boiling hot, it is decomposed with great rapidity, accompanied by a copious extrication of sulphureous acid gas and violent effervescence. If the mixture is distilled to dryness, a small quantity of sulphur sublimes into the neck of the retort, and a mass of sulphated oxyd remains at the bottom of the vessel. When the process is stopped short of desiccation, a white, soft, moist, and bulky mass is produced, which, when washed with a little water, deposits a large quantity of white oxyd; the supernatant liquor is considerably acidulous, and holds in solution a little antimonial oxyd, which, however, is separated by the addition of a fresh portion of water. The same effect is produced by simply heating the fluid, or by the addition of an alkaline lixivium.

The *Sulphureous acid*, whether hot or cold, appears to be incapable of acting on reguline antimony: it will however decompose most of the salts of this metal, especially that produced by the muriatic acid; a white pulverulent precipitate

is thrown down on the addition of sulphureous acid, which appears to be a true insoluble sulphate of antimony; it is of an acrid and harsh taste, and is decomposable by mere heat, or with extrication of sulphureous acid by the sulphuric. In the former case, a reddish brown sulphuretted oxyd is produced, which is soluble in caustic potash, and precipitable by muriatic acid, from its solution in the form of kermes or hydrosulphuretted oxyd of antimony.

The *Nitric acid*, especially when fuming, is rapidly decomposed upon antimony, even in the cold: a large disengagement of nitrous gas takes place, and the metal is converted into a white oxyd. If the antimony is reduced to fine powder, and mingled with only as much acid as is requisite to form a thin half fluid mass, the mutual action of the ingredients is so rapid as to cause actual inflammation. In their strong affinity for oxygen, a remarkable analogy subsists between antimony and tin; for not only the nitric acid, but even the water with which it is mixed, are decomposed by the antimony; the azot of the former, and the hydrogen of the latter of these fluids combine during their nascent state, and produce ammonia, which, uniting with part of the undecomposed acid, occasions the unexpected appearance of crystals of nitrated ammonia, and these have sometimes been mistaken for nitrat of antimony. The presence of ammonia in the white oxyd, thus formed, may be further shown by mingling it, before it has been washed, with quicklime, or caustic potash, when ammoniacal gas will be immediately disengaged. After the action of the nitric acid the greater part of the antimonial oxyd will be found undissolved at the bottom of the vessel, but a small portion is held in solution by the supernatant acid; even this little, however, is precipitated by water, by evaporation, or by exposure, for a few days, to the open air. The white nitrated oxyd appears to be a saturated combination of antimony with oxygen, in the proportion, according to Thenard, of 70 of metal to 30 of oxygen. It is considered as one of the most refractory and irreducible of the metallic oxyds, when treated in the usual way with the common fluxes; but when mingled with a little regulus of antimony, and heated in a close vessel, it becomes, in succession, yellow, orange, brown, and then black, in which state it contains only 2 *per cent.* of oxygen, and is easily reducible by fusion with a little tartar.

Muriatic acid, when heated, is capable of dissolving a small proportion of antimony, of which

* An. de Chim. vol. xxxviii. & xli.

a part is again deposited in the form of a white oxyd, as the liquor cools; the remainder, by gentle evaporation, may be obtained in small needle-shaped deliquescent crystals. If oxyd of antimony is substituted for the pure metal, a considerably greater proportion is taken up by the acid; this muriat, according to Monnet, crystallizes in brilliant plates, like boracic acid, and is decomposable by water.

Muriat of antimony, when deprived of its superfluous water by gentle evaporation, so as to be of a thick honey-like consistence, is volatilizable without decomposition by a moderate heat in close vessels, and concretes in the form of a soft, white, half-solid mass, called *butter of antimony*. It is not, however, by evaporation and distillation of the liquid muriat that butter of antimony is usually prepared, it being found more effectual and economical to have recourse for this purpose to one or other of the following methods. Take one part of reguline antimony, and two or two and a half parts of corrosive muriat of mercury (corrosive sublimate) mix them accurately by trituration in a Wedgewood ware mortar, and then transfer the mass into a wide-necked glass retort, fitted with a common receiver; a gentle sand heat being applied, there will first rise a small quantity of a clear liquid, which is to be removed, and afterwards a thick liquor will come over, and concrete in the receiver and neck of the retort into solid butter of antimony: the residue in the retort consists of mercury and oxyd of antimony, combined with a small proportion of muriatic acid. The cause of this change is obviously owing to the superior affinity for oxygen possessed by the antimony, by which both the oxygen and acid are transferred from the mercury, and combined with the former metal, while the separation of the butter of antimony from the oxyd, and from the running mercury depends on its greater volatility. There are two objections however to this process; first, that if an excess of corrosive sublimate is made use of, a small portion of it is apt to rise with, and be dissolved in the butter of antimony; secondly, that if there is an excess of antimony, the produce of salt is very much diminished. A much more advantageous way of preparing this salt is to take equal parts of *unwashed* sulphat of antimony and common salt, and distil the mass to dryness. Butter of antimony is solid at the usual temperature of the atmosphere, but liquefies with a very gentle heat, and by slow cooling, crystallizes in parallelepipeds. It is intensely caustic, and destroys

the organization both of vegetable and animal substances; by exposure to the air and light it becomes coloured, and deliquesces into a thick oleaginous fluid; when dropped into pure water it is in a great part decomposed, a copious white precipitate being thrown down, consisting of oxyd of antimony, combined probably with a little muriatic acid; the remainder of the acid holding a small quantity of antimony, still in solution, mixes with the water. The white precipitate obtained in this process, after being washed and dried, forms the *powder of Algarotti*, (so called from Algarotti, an Italian, its inventor) or *Mercurius vite*. If sublimed muriat of antimony is mixed with an equal weight of nitric acid, the liquor becomes immediately very highly coloured, copious orange fumes are disengaged, a considerable heat is excited, and a white oxyd is gradually deposited. If before the latter effect takes place, the liquor is evaporated to dryness, a pure white oxyd remains behind, and this again abstracted with nitric acid, and then heated to redness in a crucible, assumes the appearance of a pulverulent mass, white externally, with a tinge of rose colour within: it was known by the old chemists, and is described, in the ancient pharmacopoeias, under the name of *Bezoar mineral*, and is in fact nothing else than a very perfect oxyd of antimony.

The *oxygenated muriatic acid*, when in the state of gas, exerts a very striking action on reguline antimony: if this metal, previously reduced to fine powder, is thrown by small quantities at a time, into a vial filled with the acid gas, each parcel will take fire, and burn with a bright flame, throwing out at the same time a number of sparks, and forming a beautiful shower of fire; the antimony is found at the bottom of the vessel, converted into the white muriatic oxyd. The liquid acid oxygenates the metal, and dissolves a small part of it: but it has not yet been ascertained whether this compound is a muriat or oxymuriat of antimony, probably, however, it is only a muriat.

The best solvent of reguline antimony is *nitro-muriatic acid*, composed of three parts of strong muriatic acid, and one part nitric acid. If the acid is made somewhat warm, and the metal added by small pieces at a time, taking care not to add a second till the preceding portion is completely dissolved, it may thus be charged with a large proportion of antimony, a small part of which only is deposited by cooling. This, however, like all the foregoing antimonial salts, is decomposable by the addition of distilled

water: a piece of iron or zinc throws down the metal in the state of black oxyd, which, when dried at a low temperature, has been observed by Thenard, to exhibit the properties of a pyrophorus, inflaming spontaneously by exposure to the air.

The *Fluoric* and *Boracic acids* have no action on reguline antimony; but when digested on the grey oxyd of this metal they combine with it, and form crystallizable salts, the properties of which have not yet been examined.

The *arsenic acid*, when digested upon reguline antimony, produces two compound substances; one remains insoluble at the bottom of the fluid, and consists of the oxyds of arsenic and antimony, being an arsenite of antimony; the other is dissolved in the supernatant liquor, and is either a true arseniat of antimony, or, perhaps, differs from the insoluble residue only, in containing a smaller proportion of antimony. The former of these salts is soluble in muriatic acid, from which it is precipitable by water. ^b If dry arsenic acid and regulus of antimony are distilled together, as soon as the mass becomes fluid, an inflammation takes place, regulus of arsenic sublimes into the neck of the retort, and what remains behind is a mixture of the oxyds of arsenic and antimony. Arsenic acid has no effect on the sublimed muriat of antimony, but the neutral arseniats decompose it without difficulty, throwing down an arseniat of antimony.

The effect of the vegetable acids upon metallic antimony is scarcely perceptible: those however of its oxyds which are not saturated with oxygen are soluble without much difficulty. *Tartareous acid*, by long digestion, may be made to take up about one-third or one-fourth of its own weight of antimonial oxyd: the solution, when evaporated and cooled down to the proper temperature, deposits a few crystalline grains of *tartrate of antimony*; by far the greater portion, however, is of a gelatinous consistence, and has not been much examined. *Tartrate of potash* will also take up nearly as much antimonial oxyd as tartareous acid does; the liquor becomes slightly alkaline, and deposits, by evaporation, a number of crystalline grains. But the combination of cream of tartar, or acidulous tartrate of potash, with antimony, commonly known by the name of *emetic tartar*, is that which, from its importance in medicine, has been the most accurately examined.

A solution of tartareous acidulum takes up at a boiling temperature a considerable proportion

of oxyd of antimony, and by evaporation and cooling deposits elongated octahedral crystals of emetic tartar. As, however, the materials of this salt are hardly ever perfectly pure, and as the method of preparing it is by no means uniform; the efficacy of this important medicine is liable to considerable variation, as well as the analyses that have been published of its component parts. Common cream of tartar is always contaminated with a small quantity of tartrate of lime, and the glass of antimony which is the antimonial oxyd generally made use of, contains, besides, a variable proportion of sulphur, as well as some filix, from the earthen crucibles in which it is made, and which are, in some degree, corroded by it. In order, therefore, to prepare a pure and uniform emetic tartar in the most economical manner, the following directions must be carefully attended to.

Take 12 ounces of glass of antimony, and reduce it to a very fine powder, to which add a boiling hot solution of 16 ounces of cream of tartar in 14 quarts of rain water; put the whole in a proper vessel on a digesting sand bath, and keep stirring it with a stick for the space of half an hour; the liquor will soon be covered with a brownish froth, and some sulphuretted hydrogen gas will be given out; when the disengagement of this gas begins to cease, make the solution boil gently for about ten minutes, after which, remove the vessel from the fire, and when the liquor is become clear, transfer it into a clean evaporating dish, and, by a very gentle heat, reduce it almost to dryness, in order to precipitate the filix, which would otherwise convert the whole to a gelatinous mass, and prevent, in a considerable degree, the after crystallization: when the salt is nearly dry, add hot water as long as any thing continues to be dissolved; then strain the liquor, which will be of a bright wine colour, and evaporate it to a pellicle: by standing for a night, a number of octahedral and tetrahedral crystals will be deposited, which are pure antimonial tartar, and by further evaporation and cooling, a fresh quantity may be obtained, being altogether somewhat more than the tartar made use of. The taste of this triple salt is slightly harsh and metallic: it reddens vegetable blues, as do almost all the other metallic salts. When exposed to the air it loses its transparency, and becomes covered over with a white powder. It requires for its solution about forty times its weight of boiling water and nearly twice as much as the common temperature. Sulphuric acid precipi-

tates from it a fulphated oxyd of antimony, leaving the tartar nearly pure: the alkalies, both the caustic and carbonated, effect only a partial decomposition, a loose white oxyd being precipitated by the first, and by the second, a carbonated oxyd, which, after a time, crystallizes in the form of divergent rays. If either tartareous acid, or tartrate of potash, is added to the solution of antimoniated tartar, previously to pouring in the alkali, there will be no precipitate, for the tartrate of potash, produced by the addition of the alkali, immediately redissolves the antimonial oxyd. A simple solution of emetic tartar is for the same reason incapable of being totally decomposed by any quantity of alkali, and hence probably have arisen the great seeming differences in the constituent parts of this salt, according as it has been analysed by means of a pure alkali, a carbonated alkali, or other reagents. According to Thenardⁱ the pure crystals of emetic tartar, from whatever antimonial oxyd they have been prepared, and whatever has been the proportion of ingredients employed, contain, in a given weight, precisely the same quantity of antimony, of tartareous acid, of potash and water, and even the degree of oxydation of the metal is also invariable. His method of analysing this salt is first to ascertain its water of crystallization, by drying in a heat just not sufficient to decompose it; secondly, to dissolve the emetic tartar, and precipitate the antimony by sulphuretted hydrogen; thirdly, to ascertain the tartareous acid by the addition of acetite of lead, as long as any precipitate is produced; and lastly, to determine the quantity of potash, by igniting the residue, and extracting the alkali by diluted nitric acid. By a very careful analysis, conducted according to the above method, M. Thenard found 100 parts of emetic tartar to contain 38 oxyd of antimony,

34 tartareous acid,

16 potash,

8 water,

—
96

4 loss

—
100
—

but the tartareous acidulum, which supplies both the acid and alkali to the emetic tartar, contains 57 tartareous acid, 33 potash, and about 10 water and loss; or 70 tartrate of potash, and 20 tartareous acid, in excess; hence

it follows that the mother water remaining from the preparation of emetic tartar, contains an antimoniated tartrate of potash, which salt is necessarily mixed with the former, when prepared by evaporation to dryness, instead of crystallization, and must, no doubt, in some degree modify its effect upon the constitution, producing variations which are unjustly attributed to the pure emetic tartar.

Oxalic acid, by digestion with oxyd of antimony, takes up a considerable proportion, and the liquor deposits on evaporation, oxalat of antimony in small crystalline grains. This salt is sparingly soluble either in water or wine. The latter preparation has an emetic quality, and has been used in medicine, instead of the common antimonial wine. Acetite of antimony is prepared in the same way with the foregoing salt: it forms minute crystals, and was one of the first antimonial salts that was used in medicine on account of its emetic quality: it was first administered by Angelo Sala, but is now wholly superseded by the antimoniated tartar.

Of the neutral salts there are only three, the action of which on antimony has been much noticed, namely, the sulphat, oxymuriat, and nitrat of potash.

Sulphat of potash (and probably sulphat of soda) is decomposable by antimony in the dry way. This fact was first noticed by Monnet; he fused in a crucible two parts of fulphated potash, mixed with one of pulverized antimony, and obtained a yellow, caustic, semivitrified mass of antimoniated sulphuret of potash, which, when washed with hot water, was partially soluble in that fluid, and, as it cooled, was precipitated in the form of kermes, or hydro-sulphuretted oxyd of antimony. The metal therefore was oxydated at the expence of the sulphuric acid, and the sulphuret of potash resulting from this decomposition, united with the metallic oxyd, rendering it soluble in water.

Oxymuriat of potash acts with great energy on antimony, as indeed it does on all the easily combustible metals. If equal parts of this salt, and of antimony previously reduced to a fine powder, are mixed together, and struck briskly on an anvil, a remarkably loud detonation takes place; if the mixture, instead of being struck, is poured into sulphuric acid, or rather if sulphuric acid is poured upon the powder, a hissing noise is produced, red sparks are emitted, and the metal is converted into an oxyd.

Nitre and antimony in equal parts, or two parts of the former to one of the latter, being

ⁱ Ann. de Chim.

thrown into a red hot crucible, detonate with a vivid flame; the acid of the nitre is decomposed, and the metal is reduced to a perfect oxyd. The white mass remaining in the crucible is decomposed by digestion in warm water, into a soluble and insoluble part. The latter of these was formerly considered as a pure oxyd of antimony, but the experiments of Thenard show that it contains about one fifth of potash, intimately united with the oxyd, which appears to act the part of an acid. It was formerly known by the name of *reguline diaphoretic antimony*, but may be more properly denominated *antimonite of potash*, rendered insoluble by excess of oxyd. The soluble part differs from the other merely in the proportion of its ingredients; it is readily crystallizable, and may be decomposed, with precipitation of its oxyd, by any of the mineral acids.

The different combinations of antimony with sulphur have been treated of much at large both by the ancient and modern chemists; we shall therefore endeavour to give a full, though compendious summary of the established facts and modern opinions relative to this interesting investigation.

If equal parts of flowers of sulphur and reguline antimony are pulverized together, and exposed in an earthen crucible to a low red heat, they combine with each other, and melt into a dense uniform mass of a striated fracture and metallic lustre, and, in short, possessed of all the physical and chemical properties of the native grey sulphuret already described; hence, for cheapness' sake, all the preparations from the antimonial sulphuret are made with the native ore, or crude antimony, or antimony of the shops.

When the sulphuret of antimony is exposed to a red heat, with access of air, most of the sulphur, together with a small portion of the metal, is volatilized. If this operation is performed in a melting pot, surmounted with a series of aludels, the vapour condenses on the inner surface into a light pulverulent substance, called *flowers of Antimony*. These, at the beginning of the process, are of a greyish yellow colour, and consist of sulphur, with antimony either in the metallic state, or at least, very little oxydated; the next portions are orange-coloured, and those which rise towards the end of the operation are almost yellow, and consist of little else than pure sulphur. What remains behind is a grey ash-coloured oxyd, still holding a little sulphur; among the old chemists it was known by the name of grey calx of antimony;

by the moderns it is called the *grey sulphuretted oxyd of antimony*. It is most commonly prepared by slow roasting of the crude antimony in a flat dish, or reverberatory furnace.

The grey sulphuretted oxyd, when urged by a sufficient degree of heat, forms a transparent glass, possessing, according to circumstances, every shade of colour, from light yellow to the deepest hyacinthine red: this is the *glass of antimony*, or, according to the modern nomenclature, the *vitreous sulphuretted oxyd of antimony*. In order to prepare it, any quantity of the grey oxyd is put into a crucible, and kept at a low white heat till it enters into perfect fusion: soon after this has taken place, the end of a clean tobacco pipe should be dipped in, and if the matter that adheres to the pipe is transparent, and may be drawn into threads like common glass, it has been heated sufficiently: the crucible is then to be removed from the fire, and its contents are to be poured on a flat stone, or plate of copper. When the glass has become solid, it should be removed into a covered vessel, as it cracks and flies while cooling.

It sometimes happens in making the glass of antimony, that the grey oxyd begins to melt as soon as it is red hot, and continues limpid like water, without acquiring the tenacity of glass; at other times on the contrary, even the long continuance of a white heat will only bring it to a pasty consistence. In the former case, the glass is of an unusually deep colour; in the latter, it is almost yellow. This inequality arises from a difference in the oxyd: if it has been too little roasted, it flows with the first impression of the heat, but when more completely oxydated and desulphuretted, it proves very refractory: in this case, however, it may be remedied by throwing in a little crude antimony in powder, which will immediately determine its fusion and vitrification, while a portion of the antimony deprived of its sulphur, will fall to the bottom, in form of metallic globules.

If the previous desulphuration has been very slight, the oxydation will also have proceeded but a little way; and the glass produced, though possessed of a vitreous fracture, is perfectly opaque, and of a dark liver-colour; hence it has obtained the name of *Liver of Antimony*: the same name, however, has been given to a preparation of crude antimony and nitre, which will be mentioned presently.

The action of acids upon the sulphuret of antimony is, upon the whole, so similar to their action on the regulus, that it will only be necessary to point out the circumstances in which

they differ. In general, the metallic part of the sulphuret is more easily dissolved, and retained by acids, than the mere regulus is, and the sulphur of the compound is either not at all, or, at least, very slightly acted on. The sulphuric and nitric acids are decomposed with considerable energy on pulverized sulphuret of antimony; sulphureous acid in one case, and nitrous gas in the other, being copiously disengaged; the metal is oxydated, and remains intimately mixed, though no longer combined with the sulphur, very little of it being actually dissolved by these acids. The muriatic acid, even when cold, will decompose a large quantity of sulphuret, during which process there is a considerable extrication of sulphuretted hydrogen. If the mixture is heated, the whole of the metal enters into solution, leaving the sulphur at the bottom unaltered; a small portion, however, both of the sulphur and metallic oxyd is dissolved in the hydrogen, and escapes in a gaseous form; for Bergman observed, by performing this experiment, in a vessel with a long narrow neck, that the sulphuretted hydrogen in its passage through, deposited some kermes or hydrosulphuretted oxyd of antimony. The best menstruum for crude antimony is an aqua-regia, with a considerable excess of muriatic acid; by this the metallic oxyd is entirely dissolved, and the sulphur (about 26 per cent.) is left at the bottom of the vessel, in the form of a white powder, except a very small portion which is acidified.

The fixed alkalies are capable of combining in the dry way with sulphuretted antimony, forming several important preparations. If 15 ounces of pulverized crude antimony, 12 ounces of decrepitated muriat of soda, and 3 ounces of tartar are mixed together, and fused in an earthen crucible, there will be found, on breaking the vessel when cold, that it contains two substances; the upper is of a light colour, and consists of the muriated soda with a little sulphur; the inferior mass is very heavy, opaque, of a black colour, and, on being broken, exhibits a shining vitreous fracture: it has obtained the name of *medicinal regulus*, and is a simple alkalized sulphuret of antimony, the metal being nearly saturated with sulphur, and probably uncombined with oxygen. A similar preparation to this is the *ruby of antimony*, or *magnesia opalina*, differing, however, in containing less sulphur, and in the metal being slightly oxydated. It is prepared by mixing equal parts of muriated soda, nitre, and crude antimony, and

fusing the mass in a crucible; there is a large quantity of scorix in this, as in the former process, and underneath them is a compact vitreous substance, transparent in thin shivers, of a deep somewhat smoky-red colour, and brilliant metallic lustre. Neither of these preparations is deliquescent or soluble in water, on account of the small quantity of alkali that they contain. By increasing, however, the dose of alkali the mass becomes soluble: thus, if to one part of sulphuretted antimony we add two parts of pure dry pearlash, we obtain by fusion, a reddish-brown mass of alkaline sulphuret of antimony, and a little of the metal in its pure reguline state, is found at the bottom of the crucible. This alkaline sulphuret, being previously reduced to a coarse powder, is almost entirely soluble in boiling water, and, while quite hot, may be passed through a filter to separate the impurities; but as the liquor cools, a copious precipitate takes place of a bulky flocculent substance, whose colour is a deep brick red, approaching to that of the kermes insect, whence it has been called *Kermes mineral*: after the deposition of the kermes has ceased, the liquor being separated by the filter, is of a wine-yellow colour, and, upon the addition of any acid, a second precipitation is brought about of an orange-yellow powder, which is called the *golden sulphur* of antimony.

Kermes may also be prepared in the humid way, as was first shewn by Lemery in the year 1707. Since that period, a multitude of processes have been published by the French chemists for the preparation of this substance, none of which, however, appear to be improvements of Lemery's original method, which is as follows*. Put into a clean iron pan five or six parts of a lixivium of caustic potash with fifteen or twenty of water, set it over the fire to heat, and as soon as it begins to boil, throw in some well levigated sulphuret of antimony, equal in weight to one-sixteenth of the alkali; stir the mixture well, and when it has boiled for a minute or two, throw the whole on a filter, so that the clear liquor may pass through while hot; a large quantity of kermes will be deposited as the solution cools, which, after being separated from the alkaline liquor, is to be well washed, first in cold water, and then in hot, till the water comes off quite insipid: the powder being then dried in the shade by a very gentle heat, and levigated, and passed through a fine sieve, is to be kept in a glass phial for use. The alkaline liquor, when it has ceased to depo-

* Beaumé Chim. Exper. vol. II. p. 332.

fit kermes, may be made to yield the golden sulphur by saturating it with diluted sulphuric acid. In this process by the humid way, as in the other by the dry way, a partition of the sulphur takes place between the alkali and the metal, by which a portion of this last is left undissolved in the form of a grey powder, and this, by simple fusion in a crucible, is reduced to a mass of regulus.

According to the French chemists, both kermes and golden sulphur are *hydrosulphuretted oxyds of sulphuret of antimony*; and Thenard, in his experiments on the antimonial oxyds (already quoted) has given the following as the result of his analysis of these two substances. Kermes mineral contains

72.760 brown oxyd of antimony,
20.298 sulphuretted hydrogen,
4.156 sulphur,

97.214
2.786 loss

100.000

golden sulphur contains

68.3 orange oxyd of antimony,
17.877 sulphuretted hydrogen,
12. fulphur,

98.177
1.823 loss

100.000

The theory concerning their formation is, that the alkaline antimonial sulphuret coming into contact with water decomposes it; that the oxygen of the water combines with the sulphuretted metal, while its hydrogen dissolves some of the sulphur with which it is in contact, and unites to the sulphuretted metallic oxyd in different proportions, according to the different degrees of oxydation of these oxyds; that when the antimony is the least oxydated, it unites with the greatest quantity of sulphuretted hydrogen, and becomes insoluble in the alkali, forming kermes; and, on the other hand, when more oxydated, it unites with less sulphuretted hydrogen, and remains dissolved in the alkali, till precipitated from it by the action of an acid, forming the golden sulphur. Kermes may also be made by passing sulphuretted hydrogen through a solution of the muriat of antimony, and this, among others, is adduced as a proof

of the kermes containing the metal in an oxydated state.

The nature of the preparations that result from the mutual action of nitre and sulphuretted antimony depends principally on the proportion which the nitre bears to the other ingredient. The nitric acid is consumed in acidifying the sulphur, and oxydating the antimony, and the alkaline base of the nitre unites with the sulphur, (if any remains) with the sulphuric acid, forming sulphat of potash, and with the metallic oxyd. When the nitre considerably exceeds the antimonial sulphuret, as in the preparation of diaphoretic antimony, the sulphur is entirely oxygenated, and partly escapes in the form of sulphureous acid gas, while the remainder, with part of the alkali, forms sulphat and sulphite of potash; the metal also is completely oxygenated at the expence of the nitre; and the oxyd thence resulting combines with the potash in two proportions; that portion which is united to a large quantity of alkali is rendered soluble, and the other remains insoluble. Hence, when the result of the above process is lixiviated with hot water, we find dissolved in the liquor, and may obtain in a crystalline form sulphat and sulphite of potash, some undecomposed nitre and antimonial potash: the undissolved residue, or diaphoretic antimony consists of the perfect oxyd of this metal, combined with about a fifth of potash. When the nitre and crude antimony are only in equal proportions, part of the sulphur is acidified, and the metal is brought to a low state of oxydation: by the action of warm water, the mass is divided into a soluble and insoluble portion; the former consists of kermes, of golden sulphur and sulphat of potash; the latter is of a reddish brown colour, hence called *crocus metallorum*, and is probably nothing else than a sulphuretted oxyd of antimony.

Phosphorus unites with antimony, according to Pelletier¹ by projecting on the melted regulus small pieces of phosphorus, and immediately afterwards removing it from the fire, or by fusing together equal parts of glass of phosphorus and the metal, either with or without charcoal; the result is a white metallic mass of *phosphuret of antimony*, very brittle, of a lamellar structure, and breaking into nearly cubical fragments. When exposed on charcoal to the action of the blow-pipe, it emits, at the moment of fusion, a faint green flame, and then volatilizes like pure antimony in the form of white flowers.

¹ Memoires de Chimie, vol. II. p. 54.

Only one or two of the alloys of antimony are used in the arts, and even these have by no means been subjected to accurate chemical examination, of the rest we are almost entirely ignorant.

ANTIMONY and GOLD. See GOLD.

ANTIMONY and PLATINA. See PLATINA.

ANTIMONY and SILVER. See SILVER.

ANTIMONY and COPPER.

These two metals fused together in nearly equal proportions, form a hard brittle alloy of a violet colour and striated texture, which is not very soon affected by exposure to the air. Its specific gravity, according to Gellert,^m is greater than the mean of its ingredients. It is not made any use of.

ANTIMONY and IRON.

The general properties of antimony, with a very small proportion of iron, or *martial regulus*, we have already mentioned. Gellertⁿ fused together 115 grains of iron with 173 gr. of antimony, and obtained a brittle ash-coloured alloy, full of specks like rust of iron, of less specific gravity than the mean of its ingredients, and not attractable by a powerful magnet.

ANTIMONY and MERCURY. See MERCURY.

ANTIMONY and TIN.

These two metals being mixed in equal proportions, form a moderately hard, brittle, and very brilliant alloy, capable of receiving an exquisite polish, and not easily tarnished by exposure to the air; it has been occasionally manufactured into speculums for telescopes. Its sp. gravity according to Gellert^o is less than the mean of its constituent parts. See SPECULUM METAL.

ANTIMONY and LEAD.

Gmelin^p found that equal parts of these two metals produced a porous brittle alloy; one part antimony and two lead gave a homogeneous metal much harder than lead, but ductile under the hammer: one part antimony and eight lead formed an alloy more fusible, harder, and whiter than lead without impairing its ductility. According to Gellert^q, 386 gr. of lead and 333 of antimony afforded a brittle alloy, with a granular somewhat shining fracture, whose specific gravity was greater than the mean of its constituent parts. Antimony, lead, and a little copper, form TYPE-METAL.

ANTIPHLOGISTIC theory. See PHLOGISTON.

ANTHRACITE. See KOHLENBLENDE.

APATIT^a. *Native phosphat of Lime. Chaux phosphaté* of Hauy. *Phosphorite* of Kirwan.

Apatit, when pure, is soluble without effervescence in nitric acid. Its crystals are divisible parallel to the sides and extremities of a regular hexahedral prism. By distillation with charcoal, in close vessels, it gives out a phosphoric light and odour, and a little phosphorus. It is divided by the German mineralogists into the three following species.

I. Conchoidal Apatit.; *Muschlicher Apatit*; *Spargelstein*; *Chrysolithe* of Delisle and Born; *Pierre d'Asperge* of Brochant.

The colour of this mineral is yellowish or bluish green, or orange, or brownish-red. It crystallizes in regular hexahedral prisms, terminated by hexahedral pyramids with triangular faces (pyramide of Hauy); or in hexahedral prisms, terminated by wedge-shaped summits (cuneiforme of Hauy), or finally, the edges of the prism are deeply bevelled, so as to make it dodecahedral, in consequence of which the terminal pyramids have pentagonal faces (didodecaedre of Hauy). The crystals are very small, rarely equalling eight lines in height, and are slightly striated longitudinally. Externally it is shining or much shining, internally it is much shining, with somewhat of a greasy lustre. The cross fracture is flat-conchoidal, passing into uneven and splintery; the longitudinal fracture is imperfectly foliated. When broken, it flies into irregular sharp-edged fragments, which have often a tendency to the rhomboidal figure. It is generally transparent, but sometimes only translucent, gives a greyish-white streak, may be scratched readily by a knife; sp. grav. of the Spanish apatit, 3.09, of the Norwegian, 3.15.

The Spanish apatit was analysed by Vauquelin,^b and found to contain

53. 8 lime,
46.19 phosphoric acid,

92.27

This mineral is soluble without effervescence, in warm nitric or muriatic acid. When exposed to the blow-pipe it does not decrepitate nor lose its transparency: it becomes however

^a Chimie. metallurgique vol. i. p. 265. ^b Ibid. p. 272. ^c Ibid. p. 267. ^d Ann. de Chim. vol. viii. p. 319.
^e Chim. metallurg. vol. i. p. 269. ^f Emmerling, Lehrbuch der Mineralogie v. ii. p. 757. Hauy, Traité de Mineralog.
v. ii. p. 234. Nouv. Dict. d'Hist. nat. art. Apatite. ^g Journ. des Mines, v. vii. p. 19.

colourless, and then resembles rock-crystal. With borax it forms a milk-white imperfectly fused mass; when pulverized and thrown on hot coals, it does not exhibit any phosphorescence.

The Spanish apatit was first discovered by M. Launoy, at Mount Caprera, near Cape de Gata, in the Province of Murcia; it is found in a yellowish-white carious rock, accompanied with magnetic and micaceous iron ore, pyrites, and small plates of calcareous spar: the crystals are of the yellowish-green, and orange-coloured varieties; the latter of which, at first sight, are liable to be confounded with that variety of crystallized quartz called the Hyacinth of Compostella.

The Norwegian apatit includes the bluish-green and brownish-red varieties, and is found in the district of Arendahl, mixed with ferruginous hornblende, calcareous spar, and amorphous apatit.

II. Foliated Apatit. *Blättriger Apatit*; *Geiner Apatit*; *Apatite commune* Brochant.

The colour of this mineral is generally mountain green, sometimes pale yellowish-green, passing into olive-green, light wine-yellow and clove brown; it is also found of a middle tint, between flesh and rose-red, or hyacinth-red, greenish yellowish and pearl grey, and violet-blue; sometimes it is snow-white, and when transparent, perfectly colourless. The same crystal will often exhibit various shades and colours, and a few specimens are found iridescent. It is most commonly met with crystallized in regular hexahedral prisms (primitive of Haüy); in dodecahedral prisms, formed by bevelling the edges of the hexahedral prism (peridodecaedre of Haüy); in hexahedral prisms terminated by deeply truncated hexahedral pyramids (annulaire of Haüy); in the same with the solid angles at the base of the pyramids truncated (unibinaire of Haüy); in dodecahedral prisms terminated by deeply truncated hexahedral pyramids (emarginé of Haüy). The crystals are generally very small, and striated longitudinally: they are shining or much shining, with a vitreous lustre. The cross fracture is striae foliated, sometimes almost specular; the longitudinal fracture is uneven with fine grains, or imperfectly conchoidal. It is commonly semi-transparent, passing on the one side into transparent, and on the other to translucent on the edges. Its hardness is somewhat superior to that of fluor-spar. Sp. gr. 3.19 to 3.21. Its constituent parts, according to Klaproth, are

55 lime

45 phosphoric acid, with a little manganese

100

When reduced to coarse powder, and strewed on hot coals, it shines with a grass-green phosphoric light.

It is found at Ehrenfriedersdorf, in Saxony; at Schlackenwalde and Kuttenberg, in Bohemia; and at Schwartz-Leogang, in Salzburg. It accompanies the tin ores, and is mixed with fluor-spar, steatite, quartz, tin-stone, pyrites, manganese and wolfram.

III. Earthy Apatit. *Erdiger Apatit*; *Apatite terreuse* Brochant.

The colour of this mineral is reddish, greyish or yellowish white, stained superficially with brownish or Isabella yellow. It is found in mass, exhibiting sometimes an obscurely lamellar structure. It possesses little or no lustre, and has an earthy fracture, passing into the fine-grained uneven. It is opaque; half-hard, often friable. Sp. gr. 2.82 to 2.86.

It was analysed by Bertrand, Pelletier, and Donadei, and found to contain

59. lime,

2. silice,

1. oxyd of iron,

34. phosphoric acid,

2.5 fluoric acid,

1. carbonic acid,

0.5 muriatic acid.

100.0

When exposed to the blowpipe it becomes phosphorescent, and melts, though with difficulty, into an opaque white glass. If scratched with a knife, it exhibits a faintly luminous trace; when coarsely pulverized, and strewed on hot coals, it undergoes no decrepitation, but heats quietly, and is soon penetrated with a phosphorescent light, which hovers for some time over its surface, in the form of a bright green luminous vapour.*

It is found in strata, penetrated by quartz, at Logrofan, in the province of Estremadura, at the foot of a mountainous ridge called Guadalupe, where it is used as a common stone for building, and where its luminous quality has been long known and admired.

The phosphoric earth of Kobolo-Bojana, in the province of Marmarosch, in Hungary, is extremely similar to the earthy apatit. When

* Proust in Journ. de Phys. vol. xxxii. p. 243.

spread on hot coals, it gives a pale yellowish light, and, according to Pelletier's analysis,^d contains

- 1. water,
- 31. flax,
- 21. lime,
- 15.5 alumine,
- 1. oxyd of iron,
- 1. muriatic acid,
- 1. phosphoric acid,
- 28.5 fluoric acid,

100.0

In some specimens the proportion of fluoric acid is considerably less, and that of phosphoric acid is greater.

APPARATUS *Chemical*. For this important article see the Appendix to vol. 2.

APPLES, *Acid and Juice of*. See MALIC Acid.

AQUA. A term applied to many liquid preparations in chemistry, and especially in pharmacy. In the former the term is now little used; in the latter it is very generally adopted, to imply solutions of various substances in water in certain proportions, or distilled waters used in medicine. The following are occasionally used in chemistry.

Aqua Ammoniae Acetatae. A. Acetitis Ammoniae. A solution of ACETATED Ammonia.

Aqua Ammoniae Puræ, or Caustica. A solution of AMMONIA in water.

Aqua Calcis, or LIME Water.

Aqua Potassæ. A. Kali Puri. A solution of caustic POTASH.

Aqua P. Kali Preparati. A solution of CARBONATED Potash.

AQUA-FORTIS. *Eau Forte, Fr. Schiedewasser, G.* The term which assayers and workers of metals give to NITROUS acid. They distinguish two kinds of aqua-fortis, the *double*, which is common nitrous acid, and the *single*, which is the former diluted with an equal weight of water. But in many of the finer operations, a much more accurate distinction of the strength of the acid is required.

AQUA REGIA. The NITRO-MURIATIC Acid, called *Regia* on account of being the solvent for gold, the *king* of metals.

AQUA-VITÆ. *Eau de Vie.* A name commonly applied to native distilled spirits in the different countries in which they are prepared.

Hence it means *Brandy, Whisky, Malt Spirits, &c.* respectively.

AQUA-MARINE. See BERYL.

ARABIC GUM. See MUCILAGE.

ARBOR DIANÆ. See SILVER.

ARCHIL. See LITMUS.

ARDENT SPIRIT. See ALCOHOL.

ARDOISE. See THONSCHEIER.

AREOMETER. See GRAVITY SPECIFIC.

ARGENTINE. See SCHIEFER-SPATH.

ARGENTINE, *Flowers of Antimony.* See ANTIMONY.

ARGENTUM MOSAICUM. This is a metallic alloy in the form of silvery flakes, used as a pigment for giving a white metallic lustre to plaster casts, paper, porcelain, &c.

It is prepared in the following manner. Take an ounce and a half of grain tin, and the same quantity of bismuth, melt them together in a clean crucible, and stir the mass repeatedly with a clean iron rod till the two metals are accurately mixed. Then remove the crucible from the fire, and when its contents are upon the point of becoming solid, pour in an ounce and a half of warmed quicksilver, stirring it as before. Previously to using this alloy, it must be ground in a stone or earthenware mortar with white of egg and spirit varnish, and in this state applied to the intended work. When dried it may be burnished in the usual manner, and has then very much the appearance of silver.^a

ARGIL NATIVE.^b *Alumine native. Reine Thonerde. Argilla pura* Werner.

This mineral is of a snow-white, or yellowish-white colour: it is found in various sized kidney-form masses; presents a fine grained earthy fracture; is somewhat translucent at the edges, and becomes still more so when soaked in water; is soft to the touch, but not unctuous; stains the fingers; adheres slightly to the tongue, and is easily broken, being almost friable. Sp. gr. according to Bergman, 1.305.

When examined by a microscope, this substance is found to consist of minute transparent crystals, in the form of compressed prisms, terminated by blunted pyramids.

By exposure to a strong heat it loses two-thirds of its weight. It is almost wholly soluble in nitric or sulphuric acid without effervescence, and from the experiments of T. Saussure,^c appears to consist of alumine, of sulphat of lime, of a little combustible vegetable matter, and of a substance which bears a near resemblance

^d Pelletier's Mem. de Chimie, vol. i. p. 380.

^e Widenmann, Lenz, Brochant.

^a Encycloped. method. art. Argent. musicum.

^b Journ. de Physique, vol. 52. p. 287.

blance to glucine, being soluble in carbonated ammonia.

It has hitherto been only found in the garden of the college of Halle, in Saxony, and is considered by many mineralogists as not properly a natural production.

ARGILLITE. See THONSCHEIFER.

ARGILLACEOUS *Earth*. A term given by some to pure CLAY or ALUMINE.

ARGILLE KAOLIN. See CLAY *Porcelain*.

ARGILLE GLAISE. See CLAY *Potters*.

ARGILLE SCHISTEUSE. ARGILLACEOUS SCHISTUS. See THONSCHEIFER.

AROMA, or *Spiritus Rectior*, is applied to that part of odorous bodies which affects the organs of smell, and is supposed by some to be a peculiar principle. The subtlety of this principle, and the difficulty, amounting almost to impossibility, of establishing its identity, make this enquiry more curious than useful. All that can be said on the subject lies in a short compass, and will be noticed under the article OIL *Essential*, to which it may with propriety be referred.

ARRAGONIT. * *Exzentrischer Kalkstein*, Emmerling. *Arragonite*, Haüy and Brochant.

The colour of this mineral is greyish, or greenish white, or pale mountain green, but the centre of each crystal is generally violet blue and brownish red. It crystallizes in hexahedral prisms (prismatique of Haüy), the bases of which, though plane and compact, are without lustre, and the sides are striated longitudinally, and occasionally are somewhat concave; also in hexahedral prisms, the bases of which are rough with small wedge-shaped points (cuneolaire of Haüy); or in rounded and deeply striated masses (cylindroïde of Haüy). The crystals are of moderate size, and are found either single or in groups: each of those that belong to the first variety may be considered as an assemblage of rhomboidal prisms, every one of which incloses another prism in such a position that their axes cross nearly at right angles, as is obvious from the crossing of the striæ, and especially by a kind of mosaic in the centre of the prism, representing four triangles united round a common point; two of which are of a violet colour, and have their bases parallel to the sides of the prism, while the two contrary ones are of a pale whitish colour. This disposition becomes very striking when the prisms are sawn asunder in the direction of their axes and the surfaces polished. The arragonit, externally, is but little

shining; internally, however, it displays a very brilliant vitreous lustre: the fracture is obscurely foliated. It scratches calcareous spar, is semitransparent, has a double refraction. Sp. gr. 2.94.

When pulverized and spread on hot coals, it gives out a feeble phosphorescent light. Before the blowpipe it decrepitates, and at length is calcined like calcareous spar. It is soluble with effervescence in nitric acid. Klaproth, Vauquelin and Thenard have made separate analyses of it with great care, but have discovered nothing in its composition except lime and carbonic acid, in the same proportions as constitute the purest calcareous spar.

The arragonit was first ranked as a distinct species by Werner, and obtained its present name because it was originally discovered in Arragon and Valencia, where it is imbedded in fibrous and granular gypsum: it has since been found in the Pyrennees, and at Leogang, in the country of Salzburg, in a shattery argillaceous rock, or in quartz, accompanied by calcareous spar, and cupreous and arsenical pyrites.

This mineral deserves attention, as being one of the very few whose external and crystallographical characters are at variance with the results of its chemical analysis. The primitive form of calcareous spar is a rhomboid, the solid angles of which measure $104^{\circ} 28'$. but the arragonite is divisible only in two directions, and the inclination of its joints is 116° .

ARSENIC is a substance of very frequent occurrence, being found in combination with almost every other metal, as well as with sulphur and lime: the four following species however, are the only ones that by the common consent of Mineralogists are ranked as ores of this metal, the rest being considered as arsenicated ores of silver, copper, cobalt, &c. ^b

Sp. I. Native Arsenic. *Gediegener Arsenick*. *Arsenic natif*.

The colour of this mineral when newly broken, is a light lead-grey, passing into tin-white; but the surface by exposure to the air becomes yellow, then blackish grey, and at length almost black.

It occurs generally in mass, but sometimes disseminated: it does not form crystals, but kidney-shaped or clustered masses (hence called testaceous arsenic); or is found in plates or carious pieces. Its surface is rough or granular, with little or no lustre; internally it exhibits a slight metallic lustre. It acquires a polish by

* Haüy, *Traité de Mineralog.* vol. iv. p. 337. Emmerling, *Lehrbuch der Mineralog.* vol. ii. p. 681.

^b Emmerling, Brochant, Kirwan, Haüy.

friction, and emits an alliaceous odour: it is half-hard and brittle. Specific gravity, according to Brissou, 5.724—5.763.

When exposed to the blowpipe it fuses without difficulty, giving out a copious white vapour, and the peculiar odour of arsenic: by an increase of heat it burns with a bluish flame, and is wholly dissipated.

Native arsenic has not been accurately analysed, but besides arsenic, it appears always to contain a little iron (to which its fusibility is owing), and occasionally a very small portion of gold or silver.

This mineral is found only in the veins of primitive mountains, accompanied by red silver, realgar, galena, specular cobalt, kupfernickel, pyrites, &c. It occurs in the mines of Freyberg, in Saxony; at Geisberg, in Carinthia; at Nag-yag, in Transylvania; and St. Marie aux Mines, in France.

Sp. II. Arsenical pyrites, Marcasite, or Mispickel. *Arsenick-kies.* *Fer arsenical.*

The colour of this mineral, when recently broken, is a silvery white, but it soon tarnishes to yellowish, greyish, bluish or iridescent. It is met with in mass, disseminated, and not unfrequently crystallized. Its figures are, 1. A perfect, somewhat oblique-angled quadrilateral prism. 2. The same terminated by dihedral summits. 3. The same prism with convex or concave lateral faces. 4. A very acute octahedron. 5. Lenticular crystals. The size of the crystals varies from moderately large to very minute or acicular. The lateral faces of the prisms are always smooth and brilliant; the summits are transversely striated. Internally the lustre is shining and metallic. Its fracture is uneven and granular. It is hard and brittle. Sp. gr. according to Haüy, 6.52.

When scratched or struck with the hammer, the arsenical pyrites emits a strong alliaceous odour. Before the blowpipe it gives out a copious white vapour of oxyd of arsenic, a small portion of earth and oxyd of iron remaining behind in the form of an infusible powder, or of a brittle globule, if the heat has been considerable.

This mineral has not been accurately analysed, or rather appears to contain arsenic, iron, and sulphur, in variable proportions; mixed with which is occasionally found from one to ten per cent. of silver.

It is found in almost all metalliferous primitive mountains; but the variety containing silver has hitherto been met with only at Freyberg and Braunsdorf, in Saxony.

Sp. III. Sulphuret of Arsenic.

This species is generally, though perhaps unnecessarily, divided into two varieties, which however appear to pass into each other, so as to render it difficult to assign the limits of each; we shall therefore follow the example of Haüy, in referring all the crystalline forms to the first variety.

Var. 1. Realgar. *Roths Rauschgelb.* *Arsenic sulphuré rouge.*

Its colour is a bright Aurora red, passing on one side into scarlet, on the other to light orange. It is found rarely in mass, more frequently disseminated or investing, but most commonly crystallized. The primitive form of its crystals appears to be the same with that of sulphur, namely, the long octahedron, with scalene triangular faces; sometimes a quadrilateral prism is interposed between the pyramids of the octahedron, and other varieties are deduced from the truncature of the solid angles and the bevelling of the sides of the prism. The crystals are generally small and difficult to determine: they exhibit, both externally and internally, a brilliant lustre, between vitreous and waxy. The fracture is uneven granular, passing into minute conchoidal. It is commonly translucent, but occasionally also semitransparent or opaque. The colour of its streak is orange yellow: it is very tender, brittle, and may be easily broken by the nail. Sp. gr. from 3.2 to 3.3. It is idioelectric, acquiring the resinous electricity by friction.

Before the blowpipe it melts easily, burns with a blue flame, and exhales a sulphureous arsenical odour, and is almost entirely volatilized. It loses its colour by digestion for a short time in nitrous acid. It has never been accurately analysed, but consists for the most part of arsenic and sulphur.

Realgar occurs native in the vicinity of Etna and other volcanoes, and in the primitive mountains of Germany, Switzerland and Hungary. The substances by which it is usually accompanied are native arsenic, red silver, and galena.

Var. 2. Orpiment. *Gelbes Rauschgelb.* *Arsenic sulphuré rouge.*

Orpiment differs from realgar in the following particulars. Its colour is a bright lemon yellow, passing into gold yellow and aurora-red. It is found disseminated or in mass: its internal lustre is very brilliant, between waxy and semi-metallic: its fracture is straight or curved-foliated. Sp. gr. 3.4.

It is always found in stratified mountains, accompanied by clay, quartz, &c. and appears

to be a mineral of late formation. It is procured from the Bannat, from Servia, from Nag-yag in Transilvania, and Felsobanya in Hungary. The Romans procured the beautiful bright gold coloured orpiment from Syria, and esteemed it highly as a pigment.

Sp. IV. Native White Arsenic. *Naturlicher arsenick-kalk. Arsenic oxyde natif.*

Its colour is snow-white, or yellowish reddish or snow white, or smoke grey. It is commonly found in the state of a friable earthy crust, on the surface of other minerals; it is also occasionally met with stalactitic, clustered, or in minute bundled capillary crystals. In the earthy state it is opaque, but when crystallized is translucent. It is friable and very brittle. Sp. gr. 3.7.

When exposed to the blow pipe it is almost entirely volatilized in the form of a white vapour, accompanied by the characteristic odour of arsenic; the smoke-grey variety approaches to the metallic state, and therefore, when heated, burns with a very pale blue flame. It is soluble in fifteen times its weight of boiling water, leaving behind scarcely any residuum, and is probably a pure oxyd of arsenic.

This mineral is of very rare occurrence, having been met with as yet only in the cobalt mines of Bohemia and Saxony, and on the surface of native arsenic in Transilvania and Hungary.

White Arsenic, when in its purest state, appears as a beautiful white, sonorous, vitriform mass, very brittle, and easily reduced to powder. When recently prepared it is considerably transparent, but becomes opaque by keeping. It is prepared in the large way by a second sublimation of the impure arsenic, obtained in the roasting of the arsenical ores. M. Fragofo de Siqueira gives the following account of the method adopted in Bohemia.*

The subliming vessels are strong square boxes of cast iron, furnished with conical heads of the same material, closely luted to them with clay. The square boxes are disposed in a large brick area, which is heated by the flues of two furnaces placed a little below them. When red-hot, the impure arsenic is laded into the boxes by fifteen pounds at a time, where it melts, and in about an hour after it begins to sublime into the conical head. When no more rises, another fifteen pounds is put into the vessel, and treated as before; and this successive addition is continued till about 150 pounds of arsenic have been used to each vessel, the sublimation of the whole of which quantity lasts about 12 hours.

When cold, the workmen take off the conical head, and carry it with its contents to another place, where they break off with hammers the sublimed arsenic, separating any impurity for a second operation.

The yellow glass of arsenic, or artificial orpiment, is prepared in the same manner with the same apparatus, but for this the arsenic is previously mixed with half its weight of sulphur. In either case the heat should be maintained all the while uniformly red, so as to keep the materials in the lower vessel always in fusion. When these are tolerably pure, almost the whole rises in the sublimation. It is remarkable that the simple precautions taken to have a free current of air, and to avoid breathing the dust of the arsenic when the vessels are filled, are sufficient to preserve the health of the workmen employed about this hazardous metal.

The rough material of this process is the oxyd of arsenic, obtained by roasting the TIN and COBALT ores, and twice torrefied before it is used for sublimation. If these precautions are not observed, the arsenic remains yellow and grey instead of white.

As arsenic is a metal of little value in itself, and so detrimental to most other metals, by rendering them brittle and unmalleable, the analysis of the arsenical ores, with a view to the quantity of this metal, is a matter rather of curiosity than utility. When required, several methods have been proposed.

In the ores of several metals simply mineralized by arsenic, the quantity of this metal may be estimated roughly by the loss which the ore undergoes on roasting. The arsenic which is volatile in a red heat, flies off in strong garlick-smelling fumes. This way, however, is very inaccurate, for all the arsenic cannot be driven off by mere heat, nor is the residue always in the same state of oxidation after as before roasting, and consequently its weight may have altered, independant of the loss of arsenic.

For the analysis of the native arsenic, Bergman recommends to dissolve it in four times its weight of nitro-muriatic acid, slowly evaporate it as long as it remains clear, and then, by the addition of water, the arsenical oxyd will alone be precipitated. This way, however, is not accurate, as some of the arsenic remains in solution, and a small portion will probably be acidified by the nitrous acid, and form a compound with iron, besides other combinations. Zinc will also precipitate the arsenic from its solution in a reguline state.

* Journ. Phys. tom. I.

In the sulphurets of arsenic, the arsenic is slowly dissolved in marine acid, with occasional addition of the nitrous. The solution proceeds languidly, till at last only the sulphur is left untouched and in its natural state. This, collected and weighed, will indicate the quantity of arsenic in the solution. Some objection, however applies to this method, as part of the sulphur may also be acidified if the process is not carried on with extreme caution, but on the whole it appears an useful method.

The roasting of the arsenical ores is a tedious process, and requires some management. They should always be previously ground to powder, mixed with charcoal, or better with saw-dust, and kept at a low red-heat for several hours. The above admixtures render the arsenic much more volatile, by keeping it in the reguline state (at which it flies off with less heat than in any other form), and by dividing it they prevent it from clotting and running in lumps by fusion. Where the mere separation of the arsenic is required (as in estimating the quantity of iron in mispickel), the following way will be found by much the most convenient and the shortest.^a Add to the powdered ore dilute nitric acid, and digest with a gentle heat. This will dissolve all the arsenic and iron, whilst most of the sulphur, with the siliceous residue, will remain undissolved. Pour off the nitrated solution, mix with it about twice as much powdered charcoal as the quantity of ore employed, and evaporate nearly to dryness. Put the residue in a tall crucible, and apply a brisk red heat for about ten minutes, by which time the arsenic will be almost entirely driven off in copious fumes, and the residue will consist of little else than charcoal and oxyd of iron. Spread this upon a heated tile, till the charcoal is mostly burned off, by which any arsenic still adhering will be dissipated, and the remaining oxyd of iron may be reduced, or estimated in the way mentioned under that metal. The nitrous acid is preferable to the muriatic in this process, as the latter, when strongly heated, volatilizes part of the iron and renders the assay incorrect.

As a general rule in attempting the analysis of the arsenical ores by nitric or nitro-muriatic acid alone, it should be observed that where the object is a simple solution of the arsenic, with a view to subsequent precipitation, either by water or an alkali, no more acid should be employed than is absolutely necessary; since arsenic is a substance capable of complete acidification by the nitrous acid in sufficient quantity, and when

acidified, it is no longer precipitable by water or by alkalies, but acts quite a new part in the mixture.

Mispickel, a native alloy of arsenic and iron, is analyzed by Bergman by the nitro-muriatic acid. This will indeed dissolve both iron and arsenic, but by slow digestion it may be made to take up all the iron before the arsenic is much acted on.

But as in every solution of arsenic by nitric acid, some arsenic acid will probably be generated, another way of analysis is pointed out which is by far the most accurate. It is the complete acidification of the arsenic in the first instance, and afterwards uniting it with lead, which forms an insoluble compound, the proportions of which appear invariable. The following is M. Chenevix's method of analyzing mispickel, which may be applied (with proper allowances) to estimating the quantity of arsenic in any ore or mixture. Reduce the ore^c to very fine powder, and completely acidify it by nitric acid, saturate the whole acid with an alkali, which will form arseniated and perhaps a little nitrated alkali, then add nitrated lead as long as any precipitation appears. The precipitate is arseniated lead, 100 parts of which, dried at a low red heat, contain 33.2 of arsenic acid, of which the reguline metallic part may be reckoned at 22 parts. If sulphur be combined with arsenic, part of it will also be acidified in the process, and an insoluble sulphat of lead will also be formed along with the arseniat. These, however, are separated by weak nitric or by acetous acid, the arseniat of lead being soluble in this menstruum, but not the sulphat of lead. Hence the difference of weight between the precipitate before and after treatment with the latter acid, will shew the proportions of the arseniat and sulphat of lead.

Regulus of Arsenic, or *Arsenic*, properly so called, may be prepared in several ways, and the most convenient substance for procuring it is the common white arsenic of the shops. This is a simple oxyd of the metal, and it may be reduced by heating with any carbonaceous matter; but as arsenic in a metallic state is even more volatile than its oxyd, the common mode of fusion will not answer, as the metal will escape in dense fumes as fast as it is produced. Sublimation must therefore be used, the white arsenic and its reducing flux being heated together in close vessels, and the fumes of the reguline arsenic being condensed on a cooler part of the same or an adjoining vessel. The

^a Own Experiments.

^c Phil. Transf. vol. 91.

following mode is simple, easily performed, and makes an interesting experiment in the small way. Mix white arsenic with oil into a mass of the consistence of soft dough, drop it into a dry Florence flask, taking care not to soil the neck as the mixture passes down, put the vessel on charcoal, either naked or in a sand pot, and heat gradually. When hot enough, the oil begins to burn, and partly flies off in thick fumes, blackening the neck of the flask; these fumes soon acquire a strong and most offensive odour, somewhat like garlick, owing to the escape of part of the arsenic, which should be carefully avoided by the operator. The whole flask now becomes obscure, so that the process can only be judged of by the copiousness of the fumes, which presently are seen to deposit black films on the neck of the flask, like soot, but symmetrically arranged. The heat should be slowly raised, so as to redden the bottom of the flask, and when the fumes scarcely arise, and the hottest part of the vessel is found to be nearly empty, the whole may be allowed to cool. On breaking the vessel carefully, nothing is found in the bottom, as far as it was red-hot, but a light spongy coal, the remains of the oil; all above it, to the very top of the neck of the flask, is lined with a light black-grey crust, beneath which, immediately adhering to the glass and taking the impression of its shape, is a brittle black shining metallic substance, which is the regulus of arsenic. The neck of the flask is also covered with a number of beautiful greenish transparent pyramidal crystals of arsenic, oxydated by the access of air through the mouth, which in condensing assume this elegant form. To obtain the regulus more completely, the whole of the contents of the flask should be mixed together by rubbing, and put into a fresh flask without addition, and again sublimed slowly, stopping the mouth with paper, as there is now little need of giving vent to any fumes during the process. The sublimed regulus is now as perfect as it can be obtained, often crystallized, and exhibits every mark of a true metal.

The old method of preparing this metal was the following. White arsenic four parts, black flux two parts, iron filings and borax each one part, were put into a covered crucible, and hastily fused, after which the vessel was immediately removed from the fire. Much of the arsenic was dissipated in this way, but at the bottom of the crucible a blueish white regulus was found, consisting of reguline arsenic, combined with the iron into a hard alloy, the use

of the latter metal being only to detain the arsenic and prevent its volatilization.

This alloy tarnishes much sooner than the pure regulus. By sublimation in close vessels, the arsenic rises much sooner than before, but is thought still to carry up with it a small portion of iron, though the greater part is left behind.

For the most delicate chemical purposes, a beautiful regulus may be made by mixing arseniat of potash with about one-eighth of charcoal, and subliming in a close glass vessel slowly heated to redness. The regulus is beautifully brilliant and crystallized.

The regulus is equally prepared in the large way by sublimation, in earthen vessels, of the oxyd, mixed with a reducing flux.

ARSENIC when pure has the following properties: its colour is between a tin-white and lead-blue, which by exposure to air readily tarnishes, the later as it is the purer, and becomes first yellow, and then black and pulverulent; but it may be kept under water unaltered. Slowly sublimed in close vessels, it crystallizes in octahedrons: its specific gravity 8.308 to 8.310. Its hardness is about equal to that of copper, but it is quite brittle and very easily pulverizable. Of all metals arsenic is the most volatile by heat, for it begins to rise in fumes at about 356° Fahrenheit, that is, long before it melts, so that it can hardly ever be seen in a state of fusion. These fumes in the open air are dense, white, and exhale a very peculiar and noxious smell, somewhat resembling garlick, which circumstance forms one of the readiest tests for this metal or its oxyd. Arsenic suddenly heated to redness, by being thrown into a very hot crucible, takes fire, and burns with a whitish-blue flame, yellow at the edges. This combustion is also finely shewn by projecting some arsenic in fine powder, into a flask full of oxymuriatic gas: it takes fire instantly and burns with a beautiful flame.

The condensed fume of arsenic heated in close vessels is the regulus unaltered, but in the open air it condenses into a white, sometimes yellowish, mealy substance, which is the *White Oxyd of Arsenic*, similar to the common *white arsenic* of the shops. This oxyd is also volatile *per se*, but requires for the purpose a greater heat than the reguline arsenic, and when mixed with earthy substances it acquires so much fixity as to prove a most powerful flux. See GLASS.

White oxyd of arsenic is more soluble in water than any other metallic oxyd. About 80 parts of cold water dissolve one part of white arsenic, but no more than 15 or 16 of boiling

water are required. Much is deposited by cooling, but much more is left in the solution than cold water alone could take up. This solution is clear and colourless, has a sharp warm taste, very permanent to the tongue and somewhat sweet, and exciting nausea. It reddens litmus tincture, but does not cause any effervescence with carbonated alkali or earth. It does not alter syrup of violets.^f When slowly evaporated, the oxyd separates in minute crystals, which are long, many-sided, truncated at both ends, and often radiated or feathery. The most regular form seems to be a three-sided pyramid. These crystals exposed to the air fall into a mealy powder, in which they differ from the native and sublimed crystallized oxyds, which are permanent.

Alcohol dissolves about $\frac{1}{80}$ of its weight of white arsenic. This oxyd is entirely volatile when heated without addition, and sublimes unaltered, and in this respect it differs from all other metallic oxyds, most of which are permanent, and flow into a coloured glass by intense fire. To sublime the white oxyd of arsenic for experiment,^g a common phial should be half filled with the oxyd, loosely stopped, and put into a crucible with sand, no deeper than the height to which the bottle is filled. A brisk heat may be then applied, and the oxyd rises and condenses on the upper part of the bottle, but it requires a long continued heat to sublime the whole. The upper part of the sublimate is usually in a vitriform state, but very regular crystals may be found dispersed through it, generally octahedral. The heat at which the oxyd begins to evaporate is about 383° Fahr.^h or somewhat higher than the evaporating point of the regulus. The fumes are equally strong-smelling and garlicky, and extremely noxious to breathe. The oxyd, mixed with borax or soda, and heated with the blowpipe, runs into a yellow glass, so that it is mostly kept down by the saline flux. The specific gravity of the solid vitriform oxyd of arsenic is about 5.0; that of the crystallized, about 3.7.

From the ready solubility of this oxyd, and its strong sensible properties, it was long conjectured to possess somewhat of an *acid* nature. The admirable experiments of Scheele have fully cleared up this point, and have shewn that arsenic is capable of complete acidification, forming a very singular substance, which we shall presently mention, and that the white oxyd is in a state intermediate between the regulus and the perfect acid. Some chemists have

therefore termed it the *arsenious* acid, conformably with the new nomenclature, but as the acid properties are scarcely sensible, the term *white oxyd of arsenic* is preferable. The component parts of this oxyd are, according to Proust, 100 parts of arsenic to 33 of oxygen. The mode of reduction has been described in the preparation of the regulus of arsenic.

We proceed to the effect of acids and other reagents on arsenic and its oxyd. The peculiar properties of the arsenic acid will afterwards be noticed, but it should be observed, that the tendency of arsenic or its oxyd to complete acidification is so great, that many acids, when acting strongly upon this metal, not only dissolve it, but proceed to convert it, totally or partially, into arsenic acid. Hence the description of the preparation of this acid is inseparable from that of the operation of the acids upon the metal or its oxyd.

Sulphuric acid, when hot, acts on arsenic slowly.ⁱ Sulphureous acid is given out, and some sulphur sublimes. The undissolved residue resembles the white oxyd. White oxyd of arsenic soon dissolves in boiling and concentrated sulphuric acid, and a granular crystalline mass is left, which however is not a perfect sulphat of arsenic, as it is partly mixed with arsenic acid. By repeated abstraction of two parts of sulphuric acid to one of the oxyd, and at last by heating the retort red hot, the residue no longer sublimes like white arsenic, but melts to a crystalline mass, which in the air becomes opaque, and deliquesces into a four liquid, consisting almost entirely of arsenic acid generated in the process. This however is tedious and difficult. By the blowpipe on charcoal it returns to the state of white oxyd.

Muriatic acid dissolves arsenic only when heated, but then easily, and with the emission of arseniated hydrogen gas. About a third of the weight of the acid is dissolved. The greater part separates by cooling into crystalline grains. The white oxyd is more readily soluble in this acid. The crystallized muriated arsenic readily sublimes when heated. The saturated solution deposits almost the whole of its oxyd by the affusion of water, a method sometimes used in analysis. A singular combination of muriatic acid, with oxyd of arsenic, termed *butter of arsenic*, is formed by distillation. This will be described when noticing the arsenic acid.

Nitric acid, even diluted, attacks arsenic violently when heated, and nitrous gas is given out in abundance. The metal is first changed

^f Pelletier.^g Ibid.^h Bergman.ⁱ Gren.

N

to the white oxyd in this process, and by more acid is dissolved, and deposits on cooling a granular nitrated arsenic. Water also precipitates the oxyd from the saturated solution. The crystals of this salt are cubical or octahedral. When heated alone, the remaining nitrous gas is driven off from the crystals, and in the process they appear to pass to the state of arsenic acid, and thus to acquire fixity in the fire, this property being a striking mark of difference between the arsenic acid and the regulus or its oxyds. An excess of nitric acid converts arsenic or its oxyd entirely into arsenic acid, as will afterwards be mentioned.

The nitro-muriatic acid may be made either a perfect and simple solvent of arsenic and its oxyd, or a method of completely oxygenating it and converting it to arsenic acid. Nitro-muriatic acid slowly digested on arsenic or its oxyd, dissolves it with little alteration, and the oxyd is mostly precipitable by water, or especially by alcohol: whereas a different management of the two acids completely acidifies the arsenic.

Fluoric acid has no action on arsenic. It dissolves the white oxyd into a crystalline fluat of arsenic, but little known.

Boracic acid acts only on the oxyd. These substances will unite by fusion, and a borat of arsenic is formed,^k partly in powder, partly in arborescent spiculæ, when dissolved and crystallized by evaporation.

The other acid salts of arsenic are but little known. In general these acids have no action on arsenic, but dissolve the oxyd (which indeed is extremely soluble in almost every menstruum), and form crystallizable combinations.

ARSENIC ACID. We are indebted to the admirable skill and sagacity of Scheele for our first knowledge of this acid, and of most of its known combinations. To prepare it, put 2 ounces of white arsenic into a retort, with 7 ounces of muriatic acid, and dissolve the arsenic by boiling: then, when still hot, add $3\frac{1}{2}$ ounces of pure nitrous acid, and again heat. The mixture soon foams, and red nitrous vapour escapes. When this last appearance has ceased, add another ounce of white arsenic, dissolve by boiling as before, and then add $1\frac{1}{2}$ ounce additional of nitrous acid, whereby the same ebullition and escape of red vapour will be renewed. Distill the whole to dryness, till a white mass remains in the retort, which should be gradually heated to redness. When the retort is cold, break it, and the dry substance within is the *concrete acid of arsenic*, which is

transparent when hot, but on cooling becomes white and opaque. Dissolved in water, it forms a strong acid liquor, leaving behind some siliceous earth, acquired from the retort, which is much corroded in the process. The concrete acid also deliquesces by keeping in a moist place, and runs into the same acid liquor.

In the above process, the use of the muriatic acid is to keep the arsenic dissolved whilst the nitrous acidifies it. If economy of the distilled nitro-muriatic acid be no object, the second addition of white arsenic and nitric acid may be spared, and the whole taken at once, that is, 3 parts of white oxyd, dissolved in 7 parts of muriatic acid, and 5 parts of nitric acid, added when the solution is effected. Towards the end, when the arsenic acid is nearly dry, the expulsion of the last-adhering portion of nitric acid is attended with a boiling up, which is apt to carry with it part of the acid of arsenic, and thus an error arises in estimating the quantity produced. To prevent it, Proust^l gently shakes the retort at this period with a rotatory motion, which much promotes the easy volatilization of the nitrous acid, prevents the ebullition, and the metallic acid thickens immediately. In applying the red heat to dry it thoroughly, it should be continued till a few crystalline streaks of sublimed oxyd of arsenic appear in the top of the retort; that is, till the acid begins to be spontaneously decomposed by heat. It is then quite pure.

A speedier way of preparing this acid is the following:^m mix together in a crucible 2 parts of muriatic acid of 1.2 of specific gravity, 8 parts of white oxyd of arsenic, and 24 parts of nitric acid of 1.25 specific gravity. Evaporate to dryness, and expose the mass to a slight red heat. The quantity of the acids recommended varies considerably, but no harm can ensue from using an excess of them, beyond the loss of acid; and on the other hand, if too little be employed for acidifying all the arsenic, it is probable that all the imperfectly oxidated portion will fly off in the heat, and the arsenic acid left behind will be equally pure.

Arsenic acid has but little taste till previously dissolved in water, when it is extremely sour. Its specific gravity when dry is about 3.391. Compared with arsenic, its oxyds, its sulphuret, or saline compounds, it is remarkably fixed in the fire, all the other arsenical preparations readily subliming it less than a red heat. In a high heat, however, the acid itself is partly decomposed, and by losing oxygen a portion of

^k Gren. Journ. de Phys. tom. 49.

^m Thomson's Chemistry.

white oxyd is generated, which sublimes. If this is done in a crucible, the clay of this vessel will be strongly attacked by part of the acid when red hot, forming a permanently fixed glass, but by repeated solution in water and filtration, most of the clay is again separated. When this acid is long heated to redness in a glass retort, this last becomes entirely corroded, so as when cold to crumble between the fingers. According to Proust, and other confirming calculations, 100 parts of arsenic in the metallic state acquire 33 of oxygen when converted into the white oxyd, and 20 additional oxygen when completely acidified. So that 100 parts of the white oxyd are composed of about 75 of arsenic and 25 of oxygen; and 100 parts of the acid contain 65.4 of arsenic and 34.6 of oxygen.

The action of the oxygenized muriatic acid on arsenic is very striking. It was first noticed by Scheele. Let the vapour of this acid (prepared from muriatic acid distilled from oxyd of manganese) be received into a vessel containing the white oxyd of arsenic and water. The acid vapour is speedily absorbed, and some hours afterwards the arsenic will be dissolved, forming two liquid strata, immiscible with each other. Let these be redistilled from a clean retort, gradually heated to redness, and the product will again be two separate liquids, of very different weight. The lowest and heaviest is a peculiar combination of muriatic acid with arsenic highly oxydated, but not to complete acidification, and from its density is called *Butter of arsenic*. The upper liquid is acid of arsenic generated by the action of the oxymuriatic acid, and dissolved in water with a portion of muriatic acid. A fresh distillation causes the *butter* to rise, and to pass into the receiver in the form of a heavy oil, whilst the perfect acid of arsenic remains, and may be obtained pure by distillation to dryness, and gently reddening the retort. The acid thus obtained in no respect differs from that prepared by the nitric acid.

Butter of arsenic is produced in most cases where, during distillation, arsenic or its oxyd is in contact with muriatic acid at the moment of its evolution, together with an excess of oxygen. It is still uncertain whether the muriatic acid first combines with the oxygen previous to its action on the metal, and what is the exact state of combination of ingredients in the metallic butter. If orpiment (or sulphuret of arsenic) be distilled with triple its weight of corrosive sublimate of mercury, two liquids pass over into the receiver, and by urging the heat, cinnabar

is sublimed. These two liquids are equally obtained (but without the cinnabar) by distilling in a sand-bath 1 part of white arsenic with 3 of common salt, and $1\frac{1}{2}$ of calcined vitriol. The heaviest liquor, which is thick and brown, but transparent, comes over first; the lightest, which is yellow and thin, succeeds. The heavy liquid is the *butter of arsenic*, which, exposed to air, sends out a white fume, and gradually absorbs the atmospheric moisture, whereby the dissolved oxyd of arsenic is slowly precipitated.^a An instant separation of the white oxyd in fine powder takes place on adding water, as is the case with the other metallic butters. The fumes of the arsenical butter are pungent, like sulphureous acid. The upper thin liquid (called by some the *oil of arsenic*) equally lets fall a white oxyd on adding water, or alcohol, or alkalies, and with the latter it effervesces. By slow evaporation crystals appear, similar in properties to those of the common muriated arsenic, but extremely volatile by heat. When corrosive sublimate is used in the preparation, all the mercury appears to remain in union with the sulphur of the orpiment, forming the red sulphuret of mercury or cinnabar. The precise difference between these two singular liquids is not well known, but they appear to be little else than muriatic acid in some form of union with oxyd of arsenic, and more abundant in the *butter*; and hence more of this, in proportion to the oil, is obtained, by letting the materials stand together intimately mixed, for some time before distillation. Dilute muriatic acid acts merely as water in separating the oxyd from both the oil and the butter; the strong acid simply remains immiscible with the butter. Arsenic decomposes corrosive sublimate equally with orpiment, and the products are, besides the butter, calomel and some running mercury.* The oxyd of arsenic, on the other hand, produces no change on corrosive sublimate, and on sublimation they each rise unaltered.

Arsenic acid forms a variety of interesting compounds with alkalies and metallic oxyds, and in this point of view it requires a separate notice. Several of these salts will be described in the succeeding article of ARSENIATS. In forming many of these compounds the acid remains unaltered, following its affinities as an acid: but in all its saline combinations, as well as in a free state, it is readily deoxygenized, more or less perfectly, by heating with any carbonaceous matter. When it has thereby lost its acid properties, it then acquires great volatility in fire.

* Bergman.

• Scheele.

and gives that peculiar odour which distinguishes heated arsenic or its oxyd. Thus, arsenic acid heated in a *platina spoon* by the blowpipe, simply melts into a glass, and gives neither fume nor smell; but heated *on charcoal* it is volatilized with a white dense smoke and a strong arsenical smell. Pelletier decomposed it by hydrogen; for on passing this gas through a solution of arsenic acid in distilled water, it soon became turbid, and a black sediment subsided, which proved to be arsenic in its reguline state. Another complicated reduction, but in which hydrogen appears to be the real agent, is the following. If a piece of iron or zinc is thrown into liquid arsenic acid, and a little muriatic acid added, a great effervescence of hydrogen ensues, and a precipitate of metallic arsenic is thrown down, mixed with arseniat of zinc, which latter is separable from the arsenic by cold muriatic acid. If the solution of the white oxyd of arsenic in water be put in similar circumstances, the precipitate is entirely metallic arsenic.^p Scheele effected the same decomposition by charcoal, for on mixing this acid with charcoal powder, putting them in a retort, driving off all the moisture, and then luting on a receiver and increasing the heat to redness, a shining regulus of very pure arsenic sublimed into the neck of the retort, mixed with oxyd of arsenic, and a little charcoal dust.

Pelletier also decomposed it by phosphorus. If a stick of phosphorus is immersed in liquid arsenic acid, in a few hours the phosphorus blackens, and in time becomes covered by a very bright black metallic coating, which is reduced arsenic; whilst the remaining liquor now contains phosphoric acid.

Arsenic acid is reduced to the state of white oxyd by digestion with its own regulus. This shews in a striking manner the encreased degree of oxidation of the acid over the white oxyd.

* * *

Arsenic is little acted on by the alkalies or alkaline earths: but the white oxyd largely, and with ease. When saturated liquid potash is digested with this oxyd, assisted by heat, a solution of the arsenic readily takes place, and gives a thick ropy tenacious fluid, of a strong ungrateful smell, which on cooling becomes brittle and hard. This has been termed *Liver of arsenic*. It is uncrySTALLIZABLE, readily miscible with water, and in the fire the oxyd mostly flies off.

Acids separate the white oxyd, but do not precipitate the whole of the metal, for a small portion always becomes converted in the process into arsenic acid, which unites with part of the alkali as any other acid, and being largely soluble in water cannot be made to precipitate by any other acid, even by those that have a stronger affinity for alkalies. The union of arsenic acid and the alkalies produces some of the most important *arseniats*, to be presently described. White arsenic is acted on by soda nearly as by potash. The carbonats of these two alkalies also dissolve white arsenic very largely. This union of white arsenic and the fixed alkalies also takes place in the dry way by a melting heat, potash fixing twice, and soda three times its weight of white arsenic, according to Bergman.

Liquid ammonia forms a white concrete mass with white arsenic, which when dry adheres to glass, but is soluble in water, and by slow evaporation gives small crystals.^q This solution is not decomposable by acids, and the metallic oxyd appears to be brought nearly to the state of perfect oxidation.

Lime and barytic-water dissolve some white oxyd, which the acids again separate. By fusion, these earths unite with white arsenic into a glass, at first transparent, but soon becoming opaque in the air. Strontian probably acts like barytes, but the other earths appear to have no specific action on the oxyd, though they readily fuse along with it, when assisted by lime or barytes, into a clear glass, to which the oxyd proves a most powerful flux. All glasses holding a large portion of this metal are apt to become cloudy by exposure to the atmosphere.

Fat oils dissolve arsenic, and more readily its oxyd, into a plastery mass. Essential oils take up some of the oxyd.

ARSENIATS. The arsenic acid unites (like the other acids) with all the alkalies, and with some of the earths and metals. These compounds are many of them highly interesting.

If the acid of arsenic be saturated with potash, so as to leave however a slight excess of acid, a neutral salt is obtained, which crystallizes with great facility, and is the *arseniat of potash*. It is procured with more ease by the distillation of white arsenic with nitre, a process well known to the older chemists, but the exact theory of the operation was not understood till Scheele's discovery of the arsenic acid.

It is very accurately performed in the following manner. Mix equal parts of white arsenic and nitre, put them into a retort to which is

^p Chenevix Ph. Transf. 1801.

^q Laffone.

added a receiver, but not luted, or better, a Woulfe's apparatus. The retort should be large, on account of the great swelling of the materials when they begin to act. Apply heat, and soon a large quantity of a very red incoercible nitrous vapour is given out, which on account of its very suffocating power should be conducted up a chimney. If passed through water, a part is condensed, but much of it passes through, and appears to be nitrous gas. From a mixture of sixteen ounces of each of the materials (arsenic and nitre) Pelletier obtained 2739 cubic inches of this gas. When the nitrous acid and gas cease to come over, and the retort is slightly red hot, the process is compleated, and the residue, dissolved to saturation in hot water, affords on cooling fine crystals of arseniat of potash, mixed perhaps with a little undecomposed nitre, from which it is easily distinguished by the form, whiteness, and heaviness of its crystals. A further evaporation and cooling afford more of this salt. Its usual form is a four-sided prism, terminated by tetrahedral pyramids. The distillation of arsenic and nitre was long known to furnish the abovementioned very fuming scarcely condensable nitrous acid, but Macquer was the first who obtained the arsenical salt from the residue, and hence it is also called *Macquer's neutral arsenical salt*. A complicated apparatus is not at all necessary to procure it; if it be no object to the chemist to preserve the nitrous acid that distills, a simple flask will answer every purpose. The acid then flies off, and the arsenical salt remains in the flask with the other residue. This salt may also be prepared in a crucible in the following way.^r Melt nitre in a crucible made red hot only at the bottom, then throw in a little white arsenic on the point of a knife, which will cause much red vapour and effervescence. Repeat this addition by intervals, till the nitre begins to flow thick and pasty. When cold, dissolve out the mass with hot water, and by due evaporation arseniat of potash will be obtained.

In all the above processes the oxyd of arsenic first becomes fully oxydated by the acid of the nitre, and immediately unites with the alkali of this salt, while the acid, partly decomposed and partly expelled by the metallic oxyd, flies off in red acid and nitrous gas. To crystallize readily, there should not be an excess of alkali, for in this case the crystals will be small and deliquescent. Therefore no more nitre should be used than is requisite to acidify the arsenical oxyd, nor should it be too much or too long

heated, for nitre loses its acid simply by heat, and thus an excess of alkali is produced.

Arseniat of potash is extremely fixed in the fire. It will bear long fusion in a red heat without decomposition. Mixed with about an eighth of charcoal powder, and heated in a close vessel, the whole of the arsenic rises in the form of very fine sublimed regulus; and the residue is a carbonated alkali mixed with part of the charcoal.

In estimating the affinities of arsenic acid to the fixed alkalies, compared with other acids, their degree of fixity in heat should be taken into consideration, for the arsenic acid is permanent at a very high temperature, and thus will take the place of a stronger acid with an alkali, when the latter acid is volatile or decomposable by fire. Thus if one part of sulphuric acid is added to two parts of arseniat of potash,^s and heated no further than to redness, the residue is a strongly deliquescent acid mass, consisting chiefly of free arsenic acid and sulphat of potash. But if the fire be urged further, the sulphuric acid is again expelled, and distills over, partly as sulphuric, partly as sulphureous acid, whilst the arsenic acid remains behind, and again unites with the alkali.

Arseniat of Soda is formed as in the preceding case, either by the direct union of the arsenic acid with the alkali, or by the decomposition of the alkaline nitrat, which in this case must be the nitrat of soda, or quadrangular nitre. The form of the crystalline salt is a hexagonal prism truncated at the extremities. To crystallize easily, it is requisite (according to Scheele) that there be a slight excess, not of acid as in the former case, but of alkali, for if more acid of arsenic be added to the solution, only a confused deliquescent mass is obtained. If one part of common salt is distilled with three parts of acid of arsenic,^t with a heat slowly encreased to redness, muriatic acid distills, and the residue is some common salt mixed with arsenic acid and soda, but with the acid in excess, and therefore uncrystallizable till this excess is neutralized by the addition of chalk or alkali.

The volatile alkali saturated with arsenic acid gives on evaporation *arseniat of ammonia*, which is not crystallizable, either when the ingredients are exactly saturated or when the acid is in excess. In the former case the form is a perfect rhomboid,^u resembling rhomboidal nitre and permanent; in the latter, the crystals are long, radiated, and deliquescent. Like the two former salts, this may be formed by distilling oxyd of

^r Scheele.^s Pelletier.^t Scheele.^u Pelletier.

arsenic with the alkaline nitrat, but here some peculiar circumstances occur. Let white arsenic and nitrat of ammonia be mixed together, and put into a roomy retort with a large receiver. The fire must here be very moderate, otherwise the nitrat would spontaneously take fire and deflagrate, as it always does when heated strongly, even without addition. The products are, fuming nitrous acid, then nitrat of ammonia and disengaged ammonia, and if too much heat is used, some oxyd of arsenic sublimes. The residue is arseniat of ammonia, in the form of a vitreous mass, but with such an excess of acid as to corrode the glass of the retort just as pure arsenic acid does, and to make it crumble between the fingers. If carbonat of ammonia is added to saturation, a great effervescence takes place, and the solution now affords the perfect rhomboidal arseniat of ammonia. This decomposition of nitrated ammonia by oxyd of arsenic, may also be performed in a crucible heated slightly red, by projecting successively small portions of the mixture. But here the excess of arsenic acid acts on the clay of the crucible, as it did on the glass of the retort in the former instance, and it requires several filtrations and solutions to deprive it of this argillaceous impurity.

Arseniat of ammonia does not retain its alkali when heated, as the two preceding salts do. When distilled it yields, first liquid ammonia, then white arsenic sublimes, and at the same time much azotic gas is given out, and at last a white mass remains quite fixed in the fire, which is pure arsenic acid; and on encreasing the heat it melts, strongly corroding the glass. The production of the azotic gas, and the concomitant sublimation of the white oxyd, are to be attributed to the decomposition of part of the ammonia, its hydrogen reducing part of the perfect acid into the imperfect oxyd, whilst its azot rises in the form of a gas.

The combinations of the arsenic acid with the earths are little known, and comparatively of little importance.

Acid of arsenic dropped into lime-water forms an *arseniat of lime*, which being scarcely more soluble than sulphat of lime, sinks to the bottom in the form of minute crystals. An excess of acid redissolves them. This salt is produced in the way of double affinity, by the addition of the nitrat, acetite, and some other salts of lime with the arseniated alkalies.

Arseniat of Magnesia is uncrystallizable and little known.

The acid of arsenic acts with great energy on many of the metals forming *metallic arseniats*, whose properties are curious and interesting. Some of these, as the arseniats of iron and copper, are found native. They will all be described under the respective metals, a few of their properties only will be mentioned here, as relating particularly to chemical analysis. The metallic arseniats may all be formed by double affinity, by adding liquid arseniat of potash to the metallic sulphats, nitrats, muriats, acetites, &c. The arseniated metal thus produced is often a precipitate. Thus if arseniat of potash is added to nitrat of silver, a brown-red arseniat of silver is produced, and the solution contains nitrated potash, with some undecomposed nitrated silver. The aqueous solution of the white oxyd of arsenic gives a dirty white precipitate. Nitrated iron gives a white precipitate with arseniat of potash. With all the salts of lead a white precipitate of arseniated lead is produced. This takes place even when arsenic acid alone is added to acetite of lead, but more slowly, the acid gradually saturating itself with the oxyd of lead before it precipitates. This arseniat is also produced when acetite or nitrat of lead is added to arseniat of copper, and it has been generally adopted in analysis on account of the apparent uniformity of the compound, consisting of 33.2 per cent. of solid arsenic acid, so that 100 grains of this acid weigh 297 grains when saturated with lead. This arseniat is insoluble in water or alcohol, and hence when arseniat of copper is decomposed by nitrat or acetite of lead, the resulting nitrat or acetite of copper may be readily separated from the arseniat of lead by alcohol. This arseniat when heated by the blow-pipe on charcoal is reduced, the arsenic flies off in dense garlic-smelling fumes, and a globule of pure lead is left behind: it is thus distinguished from the sulphat of lead. The arseniat of silver is reduced in the same manner, and a globule of pure silver left behind.

A precipitate, formed by the addition of arseniat of potash to sulphat of copper, was first pointed out by Scheele, and is called after the inventor, *Scheele's Green*. (See COPPER.)

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The compounds of arsenic with *sulphur* merit attention. Both the regulus and white oxyd unite readily with sulphur, and the result is an amorphous mass, of a fine yellow or red, according to the proportions, called in the former

case *yellow arsenic*, in the latter *sandarac* or *realgar*. Similar combinations are also found native, and have been already mentioned. The exact proportions of each vary according to circumstances, and it is not precisely determined whether the colour is more owing to these proportions or to the degree of oxygenation of the arsenic. They are given however in the best authors* to be in the *red* sulphuret 1 of sulphur to 4 of arsenic, and in the *yellow* 1 to 9 or 10. Sulphur renders arsenic much more fixed in the fire, so that the red sulphuret may be melted by moderate heat into a transparent mass, called *arsenical ruby*. When the white oxyd or the arseniates are used in the preparation, they oxygenate part of the sulphur, and hence it gives out much sulphureous acid gas. In the large way these sulphurets are prepared as pigments, and the exact process is not generally known, but it is said to be by subliming in earthen vessels iron pyrites mixed with mispickel or some of the other native ores of arsenic and iron. The iron is certainly of great service in diminishing the volatility both of the arsenic and the sulphur, for a full red heat is requisite to drive them off; and we find in the way of experiment, that a simple mixture of white arsenic and flowers of sulphur sublime too hastily to contract a very close union, and seldom produce an orpiment of a full uniform body of colour.

For experiment, the operation may be performed in a glass matrafs, slightly stopped at the mouth, and heated only at the bottom gradually to redness. Equal parts of white arsenic and sulphur well mixed, yield in this manner a red sublimate, which attaches itself to the neck of the vessel. If two parts of arseniat of potash and one of sulphur, are slowly heated, barely red, for an hour in a matrafs, a very fine realgar or red sulphuret sublimes, and the residue at bottom consists of yellow orpiment, mixed with *liver of arsenic*, or arsenic united with potash. The arsenic acid gives also a fine realgar. Six parts of liquid arsenic acid mixed with one of sulphur,† give no signs of mutual action till the water is expelled, when on encreasing the heat the whole rises rapidly, and forms a fine red sublimate of realgar, with a copious emission of sulphureous acid gas. The dry arsenic acid and sulphur, in equal parts, heated for an hour, give the same products.

The yellow and red sulphurets do not dissolve in water. The nitro-muriatic acid by heat separates the sulphur from the arsenic, by dissolving the latter: some of the sulphur flies off as sul-

phuretted hydrogen gas, whilst the remainder falls to the bottom as a grey powder.

The fixed alkalies will separate the sulphur from the arsenic in the dry way, by dissolving the former. For this, mix the arsenical sulphuret with a little potash dissolved in water, dry the mixture and slowly heat in a subliming vessel. The arsenic rises in the form of white oxyd, but only partially, much remaining behind united with the alkali, now sulphuretted. If too much potash is used, no arsenic separates, but the three substances remain united in fusion. Caustic alkali dissolves the arsenical sulphuret in the moist way, for if they are boiled together, the result is an alkaline sulphuret, holding arsenic in solution. An acid gives a bright yellow precipitate in this liquor, which is probably a hydrosulphuret of arsenic.

Quick-lime and orpiment boiled together produce a sulphuret of lime, holding some arsenic in solution. This has long been known as infallible to cause the hair to fall off where it is rubbed, and is also used as a *wine-test* to detect the presence of LEAD, which it does by making a black precipitate. By long keeping, this solution deposits minute crystals of white arsenic.

The fat oils by heat dissolve the arsenical sulphurets into a very tough fetid mass.

Sulphuretted alkalies also dissolve the regulus of arsenic by fusion, but the affinity is so weak as to be displaced by almost every other metal. A similar solution takes place by boiling a watery solution of the alkaline sulphuret with the regulus, and acids precipitate from this solution a red hydrosulphuret of arsenic. The same hydrosulphuret is produced in a simpler way by passing sulphuretted hydrogen gas through a watery solution of white oxyd of arsenic, or by mixing the sulphuretted water with the same.

Arsenic will unite with phosphorus, and a *phosphuret of arsenic* is produced in the following manner. Mix half a dram of white arsenic with a dram of phosphorus,‡ and distill with a gentle heat in a close vessel. A red sublimate is produced, and at the bottom remains a black brittle substance. The former appears, by the experiments of Pelletier, to be oxyd of phosphorus, the latter is the phosphuret of arsenic. It is obtained in greater abundance by distilling cautiously equal parts of regulus of arsenic with phosphorus. The black shining residue is the phosphuret of arsenic, and contains so much phosphorus as to require to be kept under water. Both these preparations may be made in the moist way. Equal parts of regulus of arsenic

* Gren. † Scheele. ‡ Margraaf.

and phosphorus, heated with water to boiling, unite to a phosphuret, the phosphorus melting first and then acting on the arsenic. If equal parts of the white oxyd and phosphorus are heated with water, the oxyd is decomposed, and acidifies part of the phosphorus (which dissolves in the water), while the arsenic, now deoxygenated, unites with the phosphorus, which remains unaltered.

For the union of arsenic with *hydrogen*, and the singular gas that results from this combination, see the next article.

The *alloys* of arsenic are very numerous. Arsenic added to the metals when in fusion unites with most of them, and forms an alloy, which is always brittle in proportion to the arsenic contained, and generally much more fusible than the metal with which it is thus united. It also often alters the colour of the metal, rendering the yellow metals white, and the white, grey. These alloys are mostly hard as well as brittle, and on exposure to air are apt to assume a leaden black colour. The arsenic is generally separable from these alloys by simply heating them for some time to redness, and it flies off in its distinguishing garlick-smelling white fumes. If this process is carried on too hastily, some of the other metal is volatilized. Even gold alloyed with arsenic is thus dissipated by roasting. Platina alone appears absolutely fixed in these circumstances, and it even retains a portion of arsenic so obstinately that mere heat cannot drive it off.

Even the white oxyd of arsenic, heated with the metals, becomes in part reduced to the reguline state, and unites with part of the metal, whilst the other part becomes oxygenated, doubtless by taking oxygen from the arsenical oxyd, and appears on the surface of the alloy as a coloured scoria.

The great volatility of arsenic, either reguline or oxidated, when heated, renders it difficult to unite it by fusion with the metals that cannot themselves be melted with less than a red heat. There are two or three ways however of managing this combination. One is by first bringing the metal into fusion, then throwing in the crucible the arsenic, hastily mixing them, and cooling the alloy speedily, before much of the arsenic has had time to evaporate. Some artists in this way unite arsenic and copper, by melting the copper, wrapping up the arsenic in paper, and thrusting it with hot pincers to the bottom of the melted metal, through which it immediately rises and diffuses itself pretty uniformly.

Another method is to mix the white oxyd of arsenic with charcoal, and put it at the bottom of a tall crucible, over this to spread a layer of clay, and above the clay to strew the filings of the metal, with which the arsenic is to be alloyed. By heating the crucible, the arsenical oxyd becomes reduced by the charcoal, sublimes in the metallic state through the clay, and unites with the heated metal above, fusing it down, in proportion as the alloy becomes saturated with arsenic. A third method, and the most convenient, is to employ the white oxyd of arsenic, and to mix it with an alkali (with or without a carbonaceous flux) and heat it with the metal. Soap is a very good addition in this case, as it furnishes the arsenical oxyd with both carbon from its oil, and with alkali. The latter keeps down the arsenic and renders it much more fixed in the fire, as has been before mentioned in describing the combination of these two substances. When no carbonaceous matter is present, the arsenical oxyd becomes reduced at the expence of part of the other metal, which therefore is found partly oxidated, and separates from the alloy uniting with the alkali into a scoria.

Those of the arsenical alloys which are used in the arts, such as *White COPPER*, the *LEAD* alloy for shot, arsenicated *PLATINA*, &c. will be mentioned under these metals; the following are more curious than useful, and serve to illustrate the foregoing observations. The experiments are those of Achard.²

An ounce of tin, with as much white oxyd of arsenic, distilled in an earthen retort for half an hour to redness, gave some sublimed arsenical oxyd, and in the retort remained an alloy covered with a white scoria, and weighing $\frac{1}{2}$ an ounce and 3 drams. This retained part of its ductility, but was easily broken, and exhibited in its fracture large brilliant flat blades. It was tin combined with a little arsenic. Six parts of tin melted with one of white arsenic, and nine of carbonat of potash, gave an alloy, whose fracture shewed very brilliant rhomboidal facets well crystallized. Remelted without addition, it resembled zinc in its fracture, and acquired nearly the same degree of ductility as that metal. Equal parts of oxyd of tin and white arsenic, heated together in a retort, gave a very mixed sublimate, containing also some regulus of arsenic, but the tin was not quite reduced to the metallic state.

Cast *iron*, white arsenic, and carbonat of potash melted together, gave an extremely brittle close-grained alloy of arsenic and iron. Iron

² Mem. de l'Acad. de Berlin, 1781.

filings distilled with white arsenic gave a black unmetallic mass, but still attracted by the magnet. Iron saturated, or nearly so, with arsenic is not magnetical.

Lead fused with white arsenic and alkali, gave an alloy resembling that of tin in the same circumstances, but by a second fusion almost all the arsenic was expelled, so weak is the affinity between these metals in their reguline state.

As the arsenic used in all these experiments was employed in the state of white oxyd, unaccompanied by any reducing flux, and yet, as in all, a greater or less reduction of it to the metallic state took place (the alloy being necessarily in the metallic state) this reduction was obviously owing to the oxidation of a portion of that metal, whilst the reguline arsenic combined with the remainder.

Arsenic is one of the least valuable of the metallic substances. Its violent effects on the animal body when taken internally, and the easy solubility of its oxyds in almost every fluid, render it always suspicious, and often highly dangerous, when employed in the arts. The white oxyd is however largely employed as a cheap flux for glasses of different kinds, and it acts in this way in a very powerful manner; but if too much is employed, vessels made of it are not absolutely safe for domestic purposes, and are apt to become opaque. The red and yellow sulphurets afford good pigments to the painter.

The most decisive experiments for the detection of arsenic, when suspected to be contained in any substance, are the following. Boiled in water, even the white oxyd (the preparation the most likely to occur) makes a solution of sufficient strength to give very clear indications of its nature. 1st. Sulphuretted hydrogen passed through the solution, or water saturated with the gas, added to it gives a golden yellow precipitate. 2d. An extremely small quantity of carbonate of potash added to the solution, and then mixed with a solution of sulphate of copper, gives a yellowish green precipitate. 3d. The dried substance to be examined, or the solution evaporated to dryness, mixed with a little powdered charcoal, and put into a glass tube closed at the bottom, lightly stopped at the top, and heated slowly to redness, will yield a metallic sublimate, which will give the strong smell peculiar to arsenic, and will condense on the sides of the tube, lining it with a brilliant metallic coating. 4th. The same strong smell, and a dense white fume will be given, merely by

sprinkling the powder on hot charcoal. 5th. A little of the reduced regulus, or of the suspected powder, *mixed with a little charcoal*, laid between two pieces of copper (halfpence for example) scoured quite bright, bound round with wire, and heated red-hot for a few minutes, will leave on each piece of copper a bright white stain, which cannot be rubbed off, except by making a new surface. All these marks combined, cannot fail to indicate the presence of arsenic.

The affinities of the arsenic are the following. *In the moist way*, lime, barytes, strontian, magnesia, potash, soda, ammonia, alumine, and metallic oxyds. *In the dry way*, lime, barytes, strontian, magnesia, potash, soda, metallic oxyds, ammonia, and alumine.

The affinities of oxyd of arsenic are, *in the moist way*, muriatic, oxalic, sulphuric, nitric, sebatic, tartareous, phosphoric, succinic, citric, formic, arsenic, acetic and prussic acids, ammonia, fat oil and water. *In the dry way* the affinities of the regulus of arsenic are nickel, cobalt, copper, iron, silver, tin, lead, gold, platinum, zinc, antimony, alkaline sulphuret, and sulphur.

ARSENICAL NEUTRAL SALT (*of Macquer*) is the crystallized arseniate of potash, first discovered by this eminent chemist. (*See the preceding article.*)

ARSENICATED HYDROGEN GAS.

This singular gas was first discovered by Scheele,^a who on digesting zinc with arsenic acid, observed an effervescence, and the evolution of a gas with a disagreeable arsenical smell, which would not unite with water, would not diminish the bulk of common air mixed with it, and when thus mixed detonated violently on applying a candle, and left on the sides of the vessel a shining pellicle of reguline arsenic. Hence he concluded justly that it consisted of inflammable air, holding arsenic in solution. This gas has more lately been examined by Trommsdorf,^b who has ascertained many other of its properties.

There are several methods of preparing this gas. Tin, zinc, or iron filings, digested in arsenic acid, will yield it, and during the process, arsenic alloyed with the other metal is precipitated. White arsenic, dilute sulphuric acid, and iron or zinc will equally yield it; in short it appears to be given out whenever arsenic either reguline, or an oxyd, or an acid is present, under circumstances which cause the evolution of hydrogen gas. In all these instances the

^a Essays.

^b Mem. Acad. Berlin. or Phil Jour. vol. 6.

arsenic dissolved in the gas is in the metallic state, hydrogen having always a strong tendency to reduce this as most other metallic oxyds. —The precise proportions recommended by Trommsdorf, are four parts of granulated zinc, one of white arsenic, with sulphuric acid diluted with twice its weight of water. The residue, after the production of the gas, contains metallic arsenic.

Arsenicated hydrogen is a true chemical compound of arsenic and hydrogen. It has most of the properties of hydrogen, and superadded, those which would naturally be expected from the presence of a metal so combustible and easily acidifiable as arsenic. The smell is strongly arsenical, and besides being fatal when respired unmixed, it appears extremely noxious to persons much exposed to it in a room, so that experiments on it are not made without much temporary inconvenience.

Water does not absorb it, nor is litmus tincture altered by it. Its specific gravity, at 29.8 inches (English) barom. is 0.5293 (water being 1000), so that a cubic foot (English) will weigh nearly 285 troy grains, or .1649 grains the cubic inch. It is therefore heavier than sulphuretted hydrogen, and much heavier than pure hydrogen, but lighter than ammonia and all the other gasses.

The action of the oxygenized muriatic acid on this gas is very striking. When the acid, in form of gas, is passed up through a vessel of arsenicated hydrogen, the bulk is lessened, heat is given out, and arsenic is deposited on the sides of the vessel. An additional quantity produces white fumes (probably similar to those of butter of arsenic) and the metal is redissolved. By exact saturation, nearly the whole of the arsenic can thus be precipitated, and the identity of this metal can then be proved by all the experiments which the known properties of arsenic, described in the foregoing article, would suggest. When this experiment is performed over mercury, a precipitation of water is apparent. Simple muriatic gas produces no change, and hence it appears that the action of the first portion of oxymuriatic acid is to produce water by union of its oxygen with the hydrogen of the arsenicated gas, and thus to precipitate the arsenic in a metallic state; after which, however, the acid gas no longer acts upon the hydrogen, this having deposited all its arsenic, but upon the arsenic itself, and proceeds to form the muriated oxyd, and probably the arsenic acid. In confirmation of this,

the author of the above experiments, by reversing the process (that is by passing the arsenicated hydrogen into the oxygenized muriatic acid gas) observed at first the production of the white fumes only, and it was not till the former gas had been added to saturation that metallic arsenic was precipitated. Liquid oxymuriatic acid decomposes arsenicated hydrogen by mere agitation, and the result is pure hydrogen. The nitromuriatic acid acts in the same manner, but during the mixture a black precipitate is observed (doubtless arsenic), which directly afterwards disappears.

If a small quantity of fuming nitrous acid is thrown into a phial full of the gas, it becomes immediately filled with dense red fumes, and a white flame arises, and a detonation ensues. With dilute nitric acid no such appearance is observed. The residue is pure hydrogen, and the water contains arsenic acid.

Concentrated sulphuric acid added to the gas produces an immediate precipitation of metallic arsenic, which lines the glass vessel, and makes it a perfect mirror, but on agitation, the metallic coating is turned into a brown powder, which in a few days changes to red.

Sulphuretted hydrogen and arsenicated hydrogen, simply mixed, do not act upon each other, but when oxygenized muriatic gas is added, the bulk diminishes, heat is given out, and orpiment precipitates, which by encreasing the dose of the acid gas becomes of a fine orange red. This beautiful experiment will serve as a test of arsenicated hydrogen even when much diluted.

If a lighted taper is let down into a phial of this gas, it is extinguished, but the gas kindles at the surface, giving a blue lambent flame and a strong arsenical fume. As the flame proceeds gradually downwards (provided the vessel has a small orifice) the arsenic is deposited on the sides, whilst the hydrogen slowly consumes. Mixed with oxygen and kindled, the gas burns with a loud explosion, and here no arsenic is deposited, but the products are arsenic acid and water. If a stream of the arsenical gas is kindled and made to pass through a large vessel of oxygen, the flame is very brilliant.

When this gas is passed through metallic solutions, it decomposes many of them, and causes a precipitate of the two metals.

If the composition of this gas is simply arsenic dissolved in hydrogen gas, and if after the solution the hydrogen retains the same bulk which it would have when pure, the composition would be simply the following:

One cubic inch of arsenicated hydrogen weighs	grain .1649
of pure hydrogen - - - -	.0239

difference .141

so that every cubic inch of the arsenicated gas would hold in solution .141, or somewhat less than one-seventh of a grain of arsenic.

ASBEST. *Talcum asbestus*, Werner. *Asbeste*, Haüy and Brochant. *Asbest*, Emmerling.

Asbest is of a texture more or less filamentous, and by trituration is reducible to a soft somewhat fibrous powder. It is commonly divided into four varieties.

I. Amianth, or Mountain Flax. *Biegsamer asbest*, Emmerling. *Asbeste flexible*, Haüy.

The usual colour of this mineral is greenish white, passing into leek-green; or silver white, yellowish-white, ochre-yellow, pale flesh red, and, very rarely, light blue. It is found sometimes in small separate bundles, but more usually in irregular fibrous masses. Its lustre is glimmering or slightly shining, and is either weak, pearly or silky. It is easily divisible into long slender flexible fibres, may be scratched by the nail, and has a soft somewhat greasy feel. It is generally opaque, but sometimes is translucent on the edges. Its specific gravity is subject to great variety; that of the most flexible and perfectly fibrous is only 0.908; that of the most compact is 2.313.

According to a late analysis of this mineral by Chenevix it appears to contain

25.	magnesia,
59.	silica,
3.	alumina,
9.25	lime,
2.25	oxyd of iron.
98.5	
1.5	loss
100.	

Before the blowpipe amianthus melts with some difficulty into an opaque globule, which becomes dark-coloured by the continued action of the flame. If exposed to a high heat in an earthen crucible, it melts into a dense slag, strongly adhering to the vessel, of a yellowish grey colour: the surface of this slag is overspread with crystalline needles, crossing each other in all directions, or radiating from a common centre. If the heat is considerably increased, the whole melts into a green glass, and in a short time passes through the crucible. A specimen of amianthus, from Greenland, being inclosed by Klaproth^a in a charcoal crucible, and

exposed to the full heat of a porcelain furnace, fused into a finely porous mass, of a dirty pearl-grey colour, covered externally with grains of iron.

This mineral is met with in potstone or serpentine rocks, either dispersed through them or accumulated in their clefts and crevices, unmixed with any other substance. The most beautiful comes from the Tarentaise, in Savoy; it is in white-flexible filaments, sometimes a foot long, of a pure silky lustre. In some parts of Corsica it is so common as to have been used by Dolomieu instead of hay or moss, to pack up specimens of other minerals in. The islands of Elba and Crete; Zobnitz, in Saxony; Suartwick, in Sweden; Cornwall and Anglesey, in England; and Portfroy, in Scotland, also furnish considerable quantities. A compact kind, which decomposes by exposure to the air into remarkably flexible threads, is found in the Oural Mountains in Siberia.

The fibrous texture of amianthus, its incombustibility, and the little alteration that it undergoes even in a strong heat, were early noticed, especially among the Eastern nations; and methods were found out of drawing the fibres into thread, and afterwards weaving it into cloth. This, when dirtied with grease, or other inflammable matter, was cleaned by throwing into a bright fire; the stains were burnt out, and the cloth was then removed, but little altered in its properties, and of a dazzling white, hence it obtained from the Greeks the name *ασμάνθος* or *undefiled*. In the rich and luxurious times of the Roman empire, this incombustible cloth was purchased at an enormous price, for the purpose of wrapping up the bodies of the dead previously to their being laid on the funeral pile. The practice of burning the dead falling into disuse, occasioned the manufacture of amianthine cloth to be neglected, and at length entirely forgotten in Europe; but though it has ceased to be an article of necessity or luxury, yet the method of its preparation has occasionally attracted the notice of travellers and occupied the time of the curious. Ciampini,^b of Rome, in 1691, published the following as the best way of preparing the in-

^a Analyt. Ess. vol. I.

^b De incombustibili lino.

combustible cloth. Having previously steeped the amianthus in warm water, divide its fibres by gently rubbing them with the fingers, so as to loosen and separate all the extraneous matter; then pour on repeatedly very hot water, as long as it continues to be in the least discoloured. Nothing will be now left but the long fibres, which are to be carefully dried in the sun. The bundles of thread are to be carded with very fine cards, and the long filaments thus obtained are to be steeped in oil, to render them more flexible. A small quantity of cotton or wool is to be mixed, and by means of a thin spindle the whole is to be drawn out into thread, taking care that in every part the amianthus may be the principal material. The cloth being then woven in the usual manner, is to be placed in a clear charcoal fire to burn off the cotton and oil, when the whole remaining tissue will be pure white amianthus. The shorter fibres that are incapable of being woven, have been sometimes made into paper, the process for which is the same as that employed for common paper, except that a greater proportion of paste or size is required: after having been made red hot, however, this paper becomes bibulous and brittle. Amianthus threads are also sometimes used as perpetual wicks for lamps; they require, however, to be cleaned occasionally from the soot that collects about them, and the fibres in the hottest part of the flame are apt to run together, so as to prevent the due supply of oil. In Corsica, amianthus is advantageously employed in the manufacture of pottery: being reduced to fine filaments, it is kneaded up with the clay, and the vessels which are made of this mixture are lighter, less brittle, and more capable of bearing sudden alterations of heat and cold than common pottery.

II. Common Asbest. *Gemeiner asbest. Asbeste dure*, Haüy.

The colour of this mineral is leek, or mountain, or olive-green; greenish or yellowish-grey, or greyish-white. It is found amorphous, or investing other substances; the form of its filaments appears to be that of a very long rhomboidal prism: it is shining or glimmering, with somewhat of a greasy lustre: its fracture is fibrous, and much more compact than that of the amianthus, passing into the broad-striated. It flies when broken into long splintery fragments: it is translucent at the edges, and may be scratched by the nail with some difficulty. Sp. gr. 2.5. to 2.8.

The component parts of common asbest, according to Wiegand, are

48.45 magnesia,
46.66 silice,
4.79 oxyd of iron.

99.90

Asbest is of more frequent occurrence than amianthus, being found almost universally accompanying serpentine, and very often mixed with magnetic iron ore. It passes by insensible gradations into the preceding species.

III. Ligniform Asbest. *Holz-asbest. Asbeste ligniforme*, Haüy.

The colour of this mineral is yellow or Isabella brown. It is found massive, and is internally glimmering. Its fracture is thin and finely foliated: it is opaque, may be scratched by the nail, adheres to the tongue, has a meagre feel. Sp. gr. 2.051.

It is not fusible *per se* before the blowpipe.

It is met with principally in the Schneeberge of Tyrol, in the same gangue with galena, blende, common asbest, strahlstein, and gypsum.

IV. Mountain Cork. Mountain Leather. *Schwimmender Asbest. Asbest treffe*, Haüy.

The colour of this mineral is yellowish or reddish white, yellowish green or ochre yellow. It is found amorphous in thick or thin plates: it is weakly glimmering, internally. It has a thick, uneven, somewhat foliated fracture; is opaque, somewhat elastic, and floats upon water. Sp. gr. 0.68 to 0.99.

It consists, according to Bergman, of

26.10 magnesia,
56.2 silice,
2. alumine,
12.7 lime,
3. oxyd of iron.

In a strong heat it flows with difficulty into an opaque milk-white glass.

It is found in the same situations as amianthus.

ASBESTINITE. See STRAHLSTEIN.

ASBESTOID. See STRAHLSTEIN.

ASHES. *Asche*, Germ. *Cendres*, Fr.

The pulverulent residue of combustible bodies after burning is in general denominated ashes; the produce of the combustion of metals however is no longer known by the name of *metallic ashes* but of calx or OXYD. We shall therefore in the present article confine ourselves to the ashes from vegetable and animal substances.

When a *vegetable* is subjected to destructive distillation, all the native juices are more or less altered and decomposed, and fly off in the states of gas and vapour; what remains behind is a light, brittle black mass, still exhibiting very perfectly the texture of the plant, and incapable of alteration by any further degree of heat in close vessels. By the joint action of heat and air, however, the texture is destroyed, the carbonaceous matter is converted to carbonic acid gas, and a white or reddish yellow uninflam- mable powder remains behind, which is the ash or ashes. The ashes consist principally of earths and earthy salts, but contain besides alkaline and neutral salts and metallic oxyds. The earths and earthy salts are *silica*, the carbonats of magnesia and lime, the sulphats and muriats of the same, and phosphat of lime. The alkaline and neutral salts are the carbonats of potash and soda, together with the sulphats and muriats of the same. The metallic sub- stances are the oxyds of iron and manganese. The quantity of ashes is by no means propor- tionate to the solidity of the vegetable, some very compact and hard woods yielding less of this ingredient than certain succulent plants. By simple lixiviation the saline substances may be separated from the earthy and metallic parts; and this being the method in which the potash and soda of commerce are prepared, the analysis of vegetable ashes is a matter of no small im- portance: the French chemists in particular have bestowed much attention on the subject, and the results of their enquiries the reader will find detailed hereafter in the articles *CARBONAT of Potash* and *CARBONAT of Soda*.

The volatile parts of *animal* matter may be driven off with nearly the same ease as those of vegetables, and the result of each process is a spongy coal. Animal coal however is of a much greater specific gravity than that from vegeta- bles, and requires a long and intense heat for its incineration; the ashes are also more copious in proportion, and consist for the most part of carbonats and phosphats of lime and soda. For other particulars relative to animal ashes the reader is desired to refer to the articles *BLOOD*, *BONE*, *HORN*, *SHELL*.

ASPHALT. See *BITUMEN*.

ASSAY or *Essay*. *Essai*, F. *Probiren*, G.

The term *ASSAY*, in chemistry, in a general sense, implies the analysis or examination of a sample of any substance, whose chemical com- position is to be ascertained; but this term is also technically restricted to the analysis of gold and silver mixtures, with the express and sole

purpose of determining the proportion of noble metal to that with which it is alloyed, in any individual mass. It is only in this sense that we here understand it, and on account of the vast quantity of coin, plate, and plate ornaments which are constantly fabricated, the business of the assayer becomes of extreme importance; for few operations in chemistry require so nice and minute attention, and such practical experience as one, which, from the sample of a few grains, is to decide the standard of very large masses of the most valuable metals.

Gold and silver assaying is, however, in prin- ciple extremely simple, the whole being included in two operations, namely, the separation of the alloy from the noble metals, and the parting of these latter (gold and silver) from each other. These processes must be considered separately.

Of all the metals hitherto known, three alone, gold, silver, and platina, are incapable of oxi- dation by simple exposure to air, either when solid or in a state of fusion, and hence they acquired the antient name of *perfect* or *noble* metals. All the other metallic bodies tarnish and oxidate, when in fusion in open vessels, with more or less facility, and by constantly removing the oxidated surface from the melted metal, the whole may be successively converted to an oxyd. Here, therefore, is a method of separating the imperfect from the perfect metals, when the two species are mixed; namely, to melt the mixture and keep it in fusion with access of air, when the *alloy*, or imperfect metal will separate at the surface in oxidated scales, and the noble metal remain unaltered. This separation, however, is not in all cases equally exact, for when gold or silver is alloyed with a metal not very easily oxidable, though imper- fect, such as copper, and when the proportion of the alloy to the noble metal is but small, the affinity of the latter to the former encreases so much as to protect it from any further action of the air, however long the fusion is kept up. Thus a mass of eleven parts of silver to one of copper, oxidates but lightly by a long continued melting heat, nor could the whole of the copper be extracted from the mixture by heat alone. Another difficulty in the way of this separation is the very difficult fusibility of the oxyd of copper (for all metallic oxyds by heat melt into a species of coloured glass), so that in a heat much above that at which the mixture remains in fusion, the crust of oxyd clings unmelted to the surface of the fluid metal, and unless sedu- lously removed, it there remains, and prevents the further action of the air on the alloy, by

which alone all the imperfect metal can be thrown off from the mass.

But chemists have found that the separation of many of the imperfect metals is much promoted by adding to the mixture a quantity of a metal, itself highly oxidable, and its oxyd easily fusible, which unites with the original alloy of the mixture, encreases its oxidability, carries it off dissolved in the vitrified oxyd, and thus compleatly extracts from the mass all the imperfect metal or alloy, leaving the noble metal or metals pure.

A few of the more fusible white metals have been tried for this purpose, particularly lead and bismuth; but lead is found to answer the end better than any other, and is the only substance actually used. Hence litharge, the oxyd of lead, was termed by the antient chemists, not unaptly, *the bath* of the noble metals, *scouring* or *cleansing* them, as it were, from all their alloys of base metal, and leaving them quite bright and pure.

This process of oxidation of the alloy by lead is employed in the large way in the *refining* of gold and silver; in small samples, with the peculiar precautions to be presently mentioned, it forms the process of *cupellation*, which, therefore is the first and most important part of the assayers business.

The second process is the separation of the gold from the silver, where both metals are present, for being equally perfect, or unoxidable by mere fusion, they are left uniformly mixed by melting, after the alloy has been separated by cupellation. The method of separating gold from silver is by the nitric acid, which if properly managed, may be made to dissolve all the silver and leave all the gold. This process is called *Parting*, and is the second great operation of the assayer. Platina may in general be put out of the question, and it seldom is contained in any gold or silver alloy actually used, but when present it occasions some peculiar appearances, which will be afterwards noticed.

Cupellation. This process is performed in a furnace contrived for the purpose, and capable of giving a heat at least sufficient for the easy fusion of gold. (*Its construction is explained in the Appendix.*) In the middle of this furnace is placed an earthen pot called a *muffle*, of an oven form, vaulted at top, with a level floor at bottom, entirely open at one end, and closed every where else, except a few narrow slits through the sides. The open end comes in contact with a door at the side of the furnace, and is generally

luted thereto, so as entirely to separate it from the burning fuel. The body of the muffle is surrounded with the coals, and before cupellation is gradually heated to a glowing redness. Its use is to protect the small crucibles or cupels, ranged on its floor, from any accidental impurity which the fuel might furnish, and at the same time to afford the melted metal a free access of heated air to promote the oxidation. The cupels are solid pieces of earth, cubical or circular, with a shallow depression at the top to contain the metal, and small in proportion to the size of the muffle, so that the floor of this latter will hold several of them side by side. They are made solid, but at the same time so porous as freely to absorb the lead, in proportion as it oxidates and vitrifies, whilst the globule of metal that remains in the reguline state rests on the surface. Cupels may be made of any infusible earth of little cohesion, such as the ashes left after the lixivation of the residue of burnt wood, which are much employed in refining, or cupellation in the great way, but for assaying they are made entirely of bone-ash (phosphat of lime) ground to a fine powder, moistened with water, so as to take the impression of a mould, and afterwards thoroughly dried. The cores of ox-horns are preferred at the Tower Assay-Office.

The fire being kindled, the muffle and empty cupels are first heated gradually, till the whole are of a glowing red, a little powdered chalk or sand being first sprinkled on the floor of the muffle, to prevent the adhesion of the cupels by the litharge soaking through them. They are then ready to receive the metal to be cupelled. It should be observed that the cupels of bone-ash cannot absorb more than their own weight of litharge at the utmost, and hence the quantity of fine metal to be assayed should not require more lead than the weight of the cupel. The proportion of lead to the fine metal is determined by the estimated purity of the latter, as will presently be mentioned.

Experience has shewn the extreme difficulty of conducting cupellation at all times with perfect accuracy, even to persons habitually employed in this delicate operation, and many valuable series of experiments on this subject have been undertaken by able assayers, among which we may particularly mention those of M. Tillet, and his associates, nominated by the French government, and published in the memoirs of the academy in the years 1763—9—75—6—8—80—8.

Affay of Silver.

For the affay of silver, in this country, a clean piece of the metal is first taken, not more than 36 grains, and less if the alloy appears to be considerable, is laminated, and weighed with extreme accuracy in a very sensible balance. It is then wrapped up in the requisite quantity of lead, revived from litharge, and for convenience rolled out into a sheet; or else the silver and lead may be together closed in paper. The purity of the lead is of importance, as all lead only once reduced from its ore contains some silver, the quantity of which might make some notable error in the delicate operations of the assayer. But when revived from litharge lead retains no more than about half a grain of silver to the pound, which may be entirely neglected.

When the muffle and cupel are fully red hot, the silver and lead are then put in the cupel with a pair of pincers, when they immediately melt; and when red the following appearances take place. The melted metal begins to send off dense fumes, and a minute stream of red fused matter is seen perpetually flowing from the top of the globule down its sides to the surface of the cupel, through which it sinks in and is lost to view. This fume and the stream of melted matter consist of the lead oxidated by the heat and air, in one case volatilized, in the other vitrified, and in sinking through the cupel it carries down with it the copper or other alloy of the silver. In proportion to the violence of the heat is the density of the fume, the violence with which it is given off, the convexity of the surface of the globule of melted metal, and the rapidity with which the vitrified oxyd *circulates* (as it is termed) or falls down the sides of the metal. As the cupellation advances, the melted button becomes rounder, its surface becomes streaky with large bright points of the fused oxyd, which move with increased rapidity, till at last the globule being now freed from all the lead and other alloy, suddenly *lightens*; the last portions of litharge on the surface disappear with great rapidity, shewing the melted metal bright with iridescent colours, which directly after becomes opaque, and suddenly appears brilliant, clean, and white, as if a curtain had been withdrawn from it. The operation being now finished, and the silver left pure, the cupel is allowed to cool gradually, till the globule of silver is fixed, after which it is taken out of the cupel while still hot, and when cold weighed with as much accuracy as

at first. The difference between the globule and the silver at first put in, shews the quantity of alloy, the globule being now perfectly pure silver, if the operation has been well performed. The reason of cooling the globule or button gradually is, that pure silver, when congealing, assumes a crystalline texture, and if the outer surface is too suddenly fixed, it forcibly contracts on the still fluid part in the center, causing it to spurt out in arboresecent shoots, by which some minute portions are often thrown out of the cupel and the assay spoilt.

In the delicate assays for the Mint, in the Tower of London, two assays are always made of the same mass of metal, and no sensible difference between the weight of the two buttons is allowed to pass, ascertained in scales which turn with $\frac{1}{1200}$ of a grain troy. If they differ the assay is repeated.

The process is considered as well performed when the button of silver adheres but slightly to the cupel; when its shape is very considerably globular above and below, not flattened at the margin; when it is quite clean and brilliant, shewing the beautiful white of pure silver, and not in any degree fouled or spotted with any remaining litharge; and especially when the surface of the metal is disposed in scales or laminæ, the effect of a strong but hasty crystallization, which gives it a play of light and a striated lustre very different from that of a perfectly even surface of a white metal, however pure. Examined by a microscope, this striated surface is still more striking; the scales appear to affect the form of an irregular pentagon, slightly depressed at the centre, and the surface is decidedly uneven. On the other hand, when any alloy is left in the silver, the surface, though it may be quite brilliant, appears under the microscope as smooth as if varnished, and scarcely at all scaly in texture.

In common assays of plate, either gold or silver, copper is the alloy usually met with; if the fine metal be nearly pure, the cupel round the bottom is only stained yellow by the litharge; if copper is contained, it leaves a brown grey stain; the other metals, except bismuth, scarcely penetrate the substance of the cupel, but remain on the edges of its cavity in the form of coloured scoræ, of which iron is black, tin grey, and zinc a dull yellow.^b

The management of the fire is a point of great consequence in cupellation, and several important cautions are given by the most experienced assayers. When silver is kept in fusion

^a Tillet Mem. de l'Acad. 1769.

^b Vauquelin. Manuel de l'Essayeur.

in a very high heat, a portion of it is volatilized, so that if a cupel is inverted over another containing the silver thus intensely heated, the upper one will after a while be found studded over with minute globules of silver, very visible through a common lens. M. Tillet found that a button of pure silver, kept in a very high heat for two hours in a cupel, lost no less than $\frac{1}{8}$ of its weight, and hence the error which this may produce in assaying is considerable, and makes a return of a metal of less purity than is really the case. The heat is known to be too great when the cupel can scarcely be distinguished from the muffle, when the fume given off from the metal can hardly be seen for the dazzling heat, and mounts up to the dome of the muffle with great rapidity. On the other hand, when the fire is too slack, the litharge is not absorbed by the cupel, but lies on the surface as a red scoria, the circulation is sluggish, the button flat, and the fume very small. Towards the end of the operation, the heat should be gradually increased, for in proportion as the lead is abstracted from the alloy, it becomes less easy of fusion, and at last a heat fully equal to the melting of pure silver is required.

As cupellation requires a free access of air, as well as a high heat to oxidate the metal, the stopper of the furnace immediately opposite the mouth of the muffle is altogether removed as soon as the metal is put into the hot cupel, to allow a current of external air to draw in and circulate through the muffle: but to prevent this from cooling the muffle too much, a small iron platform is made to project from this orifice, on which several long cylinders of charcoal are heaped up, which, kindling on the edge of the red-hot muffle, burn with sufficient force to heat the external air in its passage to the cupels. The rapidity of oxidation is in a great measure regulated by the degree in which the mouth of the muffle is blocked up by these pieces of charcoal, being the greatest when the charcoal is no more than sufficient to keep up a due heat within, and allows the air to pass over it freely. The fuel of the furnace, which heats all the rest of the muffle, is totally unconnected with the charcoal at the orifice. The furnace should be made so that the heat of the fuel within may be readily increased or diminished, but at the same time should be able to be kept up with steadiness and regularity.

The speediest method of increasing or diminishing the heat of the assay, when the muffle is not too much crowded with cupels, is to push the cupel towards the further end of the muffle,

to where the heat is the most intense, being in the middle of the fire; or, on the other hand, to lessen the heat, to draw the cupel nearer the opening of the muffle, and remove a piece or two of the charcoal from the mouth.

The time taken to perform one silver assay from putting the metal into the hot cupel to the *lightening* or purity of the button, is in general from fifteen to twenty-five minutes, but the precise time seems to be of little consequence, the button being equally pure after a rapid as a slow cupellation. The danger of error from too great heat in volatilizing part of the silver, has been already mentioned, but at all times as much external air may be admitted into the muffle as possible, consistent with keeping up a due heat.

The proportioning the lead to the estimated quantity of alloy in the silver to be assayed, is a subject of more importance than might at first be expected. An assay is known to have had too little lead when the button is very flat, rough at the edges, dull in colour, with blackish spots, strongly adherent to the cupel, and foul with scoria on and about the button. But at first view it would seem to be immaterial how *much* lead is added, so that it be sufficient to separate all the alloy, as the whole lead, whether more or less, will equally be oxidated by the cupellation sooner or later. This is shewn by the cupellation of lead *per se*, when done to ascertain its natural quantity of silver, the whole readily scorifying in the process, and leaving only a minute globule of the noble metal. But the loss in assaying by using an excess of lead, is more than the mere waste of time and fuel, and for the following reason: M. Tillet found by experiment that when perfectly pure silver was cupelled with lead, whose natural retent of silver was known, the button of silver remaining after the process was never precisely of the same weight as before, but always a certain proportion less, even when the heat was not sufficient to drive off any of the silver. This indicated that a part must have been carried down by the lead into the cupel, and it was proved by afterwards reducing the oxyd of lead out of the cupel, and cupelling this lead by itself, when the quantity of silver left was found to be ten times as great as the natural proportion of this metal, and almost exactly to correspond to the loss of silver in the first instance. Hence it follows that the assayers report of the title or purity of any sample of silver (unless corrected) always makes the metal a little less pure than in reality, the loss of weight in the button being

entirely put to the account of alloy. When no more lead is used than necessary for the perfect separation of the alloy, M. Tillet reckons that it carries down into the cupel as much silver as, when the whole is again reduced, would make the noble metal $\frac{1}{12}$ of the mass, when the natural admixture of silver is only about $\frac{1}{152}$. But if an excess of lead is employed for cupellation, this loss of silver is somewhat greater, though it does not increase in the ratio of the excess of the lead, for ten parts of lead to a given alloy will not carry down twice as much silver as five parts, though the difference of loss will be very sensible.

It might be supposed that as the litharge of the first assay has been able to carry down a certain portion of silver into the cupel in the first instance; the same when again reduced to reguline lead could not be made to restore its excess of silver by mere cupellation *per se*. This however is not the case, for the second cupellation is found to leave a button of silver fully equal to the loss of this metal in the first assay, the lead only carrying down its natural retent of silver or nearly, that is about $\frac{1}{152}$ of its weight, as above mentioned. If the litharge of the second cupellation is again reduced and the lead cupelled a third time, an extremely small globule of silver is left, scarcely visible to the naked eye. Again reduced and cupelled, a minute grain of silver, only visible by a lens, is left on the cupel, after which the quantity becomes so small as to elude the senses. This is a convincing proof against the conversion of lead into silver by cupellation, formerly supposed by some chemists of considerable name, the silver being obviously only extracted from the lead in these processes, and not generated from it. In all these reductions the silver appears equally distributed through the lead, for M. Tillet found that separate globules of lead by accident spurted out upon an empty cupel in the muffle, each left a minute atom of silver lying upon the spot where the globules had scorified.

Bismuth will serve the same purpose as lead in cupellation, but besides that is a dearer metal and not always easily procurable, it is found to carry down with it into the cupel somewhat more of the silver than the same quantity of lead does.

As the lead must be proportioned before cupellation to the estimated quantity of alloy in the silver, a method must be found of forming this estimate with sufficient exactness. The antient assayers made great use of TOUCH-

NEEDLES, or small slips or bars of metal, made with pure silver, alloyed with known proportions of copper, in a regularly increasing series from the least to the greatest proportion ever required. The silver to be assayed was then examined in comparison with the touch-neededles, in colour, tenacity, and other external characters, and its alloy was estimated by that of the needle to which it shewed the closest resemblance. These needles are now however almost totally disused in silver assaying, an experienced assayer being able to judge of the alloy with quite sufficient exactness, by the ease or difficulty with which it is cut, the colour and grain of a fresh cut surface, the malleability, the change of surface when made red hot, and the general appearance.

Assay of Gold.

The assay of gold is somewhat more complicated than that of silver. Silver, if not mixed with gold or platina, requires only the single operation of the cupel to separate its alloy and ascertain its purity; if mixed with gold, though the latter be in a small proportion, it is called a gold assay, on account of the superior value of this metal. Copper, or any other base metal, when mixed with gold may indeed be separated from it by cupellation with lead as from silver, but it is found by experience that the affinity of copper to gold is so strong as scarcely to be overcome by this method, unless the mixture be first combined with a certain quantity of silver before cupellation. This therefore necessarily requires a subsequent operation, namely that of separating the gold from the silver when mixed in the button left after cupellation.

Gold is also frequently alloyed intentionally with silver in some foreign coins, and in some kinds of manufacture. The process of *parting*, or separating gold from silver is performed by a dilute nitric acid (or aqua fortis as it is constantly termed in manufacture) the acid dissolving the silver and leaving the gold untouched. But here another singular circumstance occurs: it is found that when the gold is in considerable proportion in the mixture, it so much protects the silver from the acid as to prevent its action more or less completely, and the parting is imperfect. Therefore, when these metals are thus mixed, it becomes necessary to add so much silver as to give this metal a great excess over the gold. About three of silver to one of gold are generally considered to be requisite, and hence the process of parting has also been called *quartation*, the relative proportion of the gold being reduced to no more than *one-fourth* of the

mas. Any greater proportion of silver than three-fourths may be parted with equal certainty, but for a particular convenience in managing the process and to save needless trouble, when silver is to be intentionally added, no more is taken than will give the above composition. It may be observed however that many good assayers consider three parts of silver to one of gold as more than necessary, and that about two will suffice.

It would seem at first sight that in gold assaying, as both silver and copper (the usual alloy of gold) are soluble in aqua fortis, the first process of cupellation might be spared, and the parting alone resorted to. This is indeed sometimes done, the gold assay piece being simply melted with the requisite quantity of silver and immediately parted by means of the acid. But as the entire quantity of materials for the assay is only a few grains, and as the intimate mixture with the silver is a point of great consequence, it is found better on the whole first to cupel them with lead (even when no copper is present and the original alloy of the gold is only silver) that they may be thoroughly combined and be collected into a small neat globule, without risk of losing or dispersing any minute portions.

The cupellation of gold therefore is conducted in the following manner. Its proportion of alloy being first estimated by the *touch*, as will presently be explained, and the small piece designed for the assay being weighed with extreme accuracy, as much silver is taken as is estimated to be necessary to make the entire quantity of this metal about thrice the weight of the pure gold; the requisite proportion of lead is also taken, and all three are put on the hot cupel, where they melt and combine almost immediately. The proportion of lead to the alloy of base metal is nearly the same as for silver assaying, the quantity will be seen by the subjoined table. The process of cupellation is conducted nearly the same as for silver, only a greater heat is required throughout in gold assaying, and this may be used with freedom, as none of the gold, or rather the mixture of gold and silver, is lost by volatilization, as pure silver is. The *lightning*, or sudden luminous brightness of the button, when all the lead is worked off, takes place here as in silver assaying, and when cooled the button is taken out and weighed. It now consists only of gold, with about three times its weight of silver; the copper, the original alloy, having been worked

off along with the litharge. Strictly speaking however, the button is not absolutely pure, as gold when cupelled with lead always retains a minute portion of this latter metal, which may be got rid of chiefly by being kept a little time in fusion on a clean vessel covered by a small crucible. The lead totally disappears after parting.^c The cold button is then flattened with the hammer, again heated red hot, and slowly cooled to anneal it and encrease its malleability, then passed between rollers of polished steel, to extend it into a small plate about as thin as a wafer, again heated only to redness, and lastly rolled up into a small loose coil. The use of the annealing is to allow the plate to roll up without cracking, and at the same time to open the texture of the metal somewhat closed by the rolling, to allow the free action of the aqua fortis in the subsequent operation of *parting*.

Before we describe this process we shall mention the way of estimating the alloy of gold before cupellation, which is necessary for giving it the due portion of lead. The fineness of silver, as we before observed, is ascertained partly by touch-needles of silver and copper, but principally by the appearance, hardness, and other external characters which experienced assayers can estimate to very great nicety. Gold is partly judged of by the same method, but it is more complicated than in the former case at least, as three metals are here concerned in the usual alloys, namely, gold, silver and copper, so that the assayer has to judge of every proportion of admixture of gold and silver, gold and copper, and often gold, silver and copper. An experienced artist, if he knows the nature of the alloy, can nearly tell its proportion by mere inspection and cutting the surface; but if touch-needles are here used, there must be several sets of them, adapted to the nature of the alloy. Four sets of these are commonly directed;^d one in which pure silver is used for the alloy, another in which the alloy is a mixture of two parts silver and one copper, a third with two parts copper and one silver, and a fourth of copper only. These are severally weighed out most carefully, with every requisite portion of the finest gold, encreasing in twenty-fourth parts, and melted together; but with the three last very little use can be made of mixtures of low denomination, for where the copper is in large quantity, the change which it gives to the colour of gold is not easily distinguished from the hue of different species of copper. In melting these mixtures, besides the

^c Tillet.

^d Lewis Comm. of Arts. p. 120.

usual precautions against accidental loss, borax is used as a flux to facilitate the union of the metals, and some pitch or tallow should be kept burning on the surface, to prevent the loss by oxidation of part of the copper, which would alter the intended proportions. As soon as ever they are melted and stirred together they should be taken out of the fire. But Mr. Hatchett's late experiments on the alloys of gold have shewn that the difficulties of producing a perfectly uniform alloy of these metals by fusion, are so great as very much to lessen the confidence to be placed in touch-needles for the smaller divisions.

Another ingenious and simple method is resorted to for estimating the proportion of gold to all other metals (platina excepted) in any alloy. It is the operation of *touching*. For this purpose a tolerably hard dark-coloured, smooth grained, even stone is selected, such as the black basalt, (or some kinds of fine black pottery will answer very well) the piece of metal to be tried is rubbed on it backwards and forwards, so as to make a broad bright metallic streak on the touch-stone, which shews the colour of the alloy, and may be usefully compared with another streak made beside it by the touch-needle, to which it bears the nearest resemblance. The colour is heightened by being wetted before examination. In this simple method, and by the assistance of good touch-needles, a practised eye will tell to great nicety the proportion of gold when the nature of alloy is known. The Chinese are said to distinguish by this means as nearly as to the 200th part of gold in the alloy of gold and silver, and in the extensive commerce of the precious metals throughout the East Indies this is said to be the only method of trial commonly adopted.

The nitric acid is also of singular service in the trial of *touching*, and is used to ascertain absolutely the quantity of gold, whether the alloy be copper or silver, or any other metal except platina. This is in fact performing in the rough way a kind of parting. When the streak on the stone has been examined by the eye, a drop of aqua-fortis is let to fall and gently spread over it. In eight or ten seconds it is washed off, and the effect observed. If the streak preserves its golden brilliance unaltered, the metal is judged to be of a certain degree of fineness; if it looks red, dull and coppery, it is less fine; if the streak is almost entirely effaced, the metal contains very little gold, and thus by that experience, which no

description can teach and nothing but actual practice can give, a good assayer will form a very tolerable judgment of the value of his sample.

But it is found in touching that pure nitrous acid, of whatever strength, will not act in any very decided manner upon the alloy of copper and gold, when this latter metal is as much as two-thirds of the mass,¹ and hence this process is chiefly of use in the lower mixtures. But if a small portion of muriatic acid is added to the nitrous, the activity of the menstruum is so much increased that any mixture below three-fourths will be acted on, and consequently the power of this operation is much extended. Gold therefore protects the alloy from the acid to a very great degree, and this is similar to what is found in parting, as the gold must not be more than a fourth, or at most a third of the mass, to allow of the separation of its alloy. The best acid for touching is recommended by Vauquelin to be 98 parts of nitric acid of 13.4 specific gravity, 2 parts of muriatic acid of 11.73 specific gravity, and 25 parts of water. This nitro-muriatic acid, it may be observed, does not act sensibly on the gold of the streak on the touchstone, the application being so short, without heat, and especially the muriatic ingredient being in such small proportion. Touching is particularly of use in judging of the value of very small samples of gold, wrought trinkets, and such pieces as cannot spare as much as six or eight grains for an assay. As it only gives the fineness of the surface which is abraded, caution is necessary where plated metal is suspected, or where the surface is artificially made finer than the inner part.

Of Parting.

The button of gold and silver left after cupellation, having been laminated and rolled into a spiral in the way above mentioned, is called a *cornet*; it is then put into a glass matraass, of a pear-form, called a *parting-glass*, and about twice or thrice its weight of pure nitric acid moderately diluted (M. Vauquelin recommends 1.25 specific gravity) is poured on it, the glass is set on a sand bath or over charcoal to boil, the mouth being slightly covered to keep out the dust. When warm, the acid soon begins to act on the silver, and dissolves it with the usual evolution of nitrous fumes. As long as the acid continues to act, the cornet is studded all over with minute bubbles; when these discontinue, or unite into a few large ones, it is a sign that the acid has ceased to act. About fifteen

¹ Lewis.

¹ Vauquelin Manuel de l'Essayeur.

or twenty minutes from the time the acid boils, is required for this process. The cornet is now corroded throughout, having lost by the solution all the silver, which was from two-thirds to three-fourths of its substance: the gold retains the same coiled form, but is very slender and brittle. It is of importance that it should not be broken, as it tends much to the accuracy of the business to have all the gold in one piece and not in fragments, and this is the chief reason why no more silver than absolutely necessary is added before cupellation; for it is obvious that the less the proportion of gold in the cornet the more likely it will be to fall to pieces on the slightest agitation. The hot acid solution of silver is then poured off with great care, and fresh acid, rather stronger, is added to clear away all remains of the silver, and boiled as before, but only for five or six minutes. It is then decanted and added to the former solution, and the parting glass is filled with hot distilled water, to wash off all the remains of the solution. This is decanted off, and at the same time the cornet, now brown, spongy and unmetallic in appearance, is got out by the following little manual dexterity. A small crucible is inverted over the top of the parting glass whilst full of water, the latter is then rapidly inverted upon the crucible, and the cornet falls softly through the water down the neck of the glass into the crucible, where it is gently deposited and the water carefully decanted off. The crucible is then dried and heated under a muffle to redness, by which the cornet shrinks extremely in every direction, becomes firm, regains its metallic lustre, and when fully red hot and cooled, it appears a small cornet of pure gold, with all the beautiful lustre, softness and flexibility of this noble metal. This is then most accurately weighed and the process is finished.

The final weight of the gold cornet indicates the absolute quantity of this metal in the assayed sample: the difference between the weight of the button after cupellation (deducting the silver added) and the first sample is the weight of the copper or other *base* metal in the gold; and the difference between the gold cornet together with the silver added, and the button after cupellation is the quantity of silver alloyed with the original gold.

The solution of silver left after parting is usually recovered by immersing in it, when collected in quantity, some bright copper plates, which dissolve and precipitate the silver in its

metallic form. It may also be recovered by a solution of common salt, which converts the silver into luna cornea, of which when washed and fully dried at a heat below redness, 100 parts indicate 75 of silver. The accuracy of the assay may be partly verified by this method.

Assay Weights.

A peculiar set of weights have been used by different nations in the assaying of gold and silver, which require to be explained. The real quantity taken for an assay is always very small, in this country generally from 18 to 36 troy grains for silver, and from 6 to 12 grains for gold. This is the integer, and whatever be its real weight it is denominated in England the assay pound. This imaginary pound is then subdivided into aliquot parts, but differing according to the metal. The *silver* assay pound is subdivided as the real troy pound into 12 ounces, each ounce into twenty pennyweights, and, for assaying, these again into halves. So that there are 480 different reports for silver (this being the number of half pennyweights in the pound) and therefore each nominal half dwt. weighs $\frac{1}{16}$ of a troy grain, when the entire assay pound is 24 grains.

The report is made according to the proportion of fine metal, thus the standard silver of the realm is reported by the assayers to be 11 oz. 2 dwt. *fine*, meaning thereby that the remainder of the pound is composed of 18 dwt. of alloy or copper, or in other terms that there are 37 parts of silver to 3 of copper. The gold assay pound is subdivided into 24 carats, and each carat into 4 assay grains, and each grain into quarters. So that there are only 384 separate reports for gold. The standard for gold coin is 22 carats *fine*, and of course 2 carats alloy. When the gold assay pound or integer is only 6 troy grains, the quarter assay grain only weighs $\frac{1}{64}$ of a troy grain. This will give an idea how accurate must be the scales used for such delicate operations.

Assayers also make their report upon gold and silver as being *better* or *worse* than the established standard. Thus gold of 20 carats would be reported as *worse* 2 carats, being that proportion less than the standard of 22 carats. We may just observe that the standard for silver of 11 oz. 2 dwt. *fine*, which long has been and is now established, was interrupted from March 25, 1697, to June 1, 1720, during which interval it was raised to 11 oz. 10 dwt. *fine*, and is called *new sterling*.^s It is distinguished by the stamp of a Britannia, whilst the *old sterling*,

^s London Goldsmith's Repository.

also resumed since 1720, has the stamp of a lion rampant. When a mixture of gold and silver is the subject of enquiry, if the quantity of gold exceeds that of silver, it is called *gold parting*: if the contrary, *silver parting*, and the return is made accordingly, but with this distinction: in silver parting the report is first made on all the fine metal collectively, as if for silver alone, so if 10 oz. of fine metal be found, the assayer reports *worse 1 oz. 2 dwt.* that is, 1 oz. 2 dwt. lower than the standard of silver.

When the assay pound is subdivided, as for silver, in the same manner as the troy pound, it is obvious that all the lower denominations bear the same relation to each other; which is some little advantage in transferring the assay reports to real mixtures for use. On the contrary, the carat subdivision for gold, is confined to assaying, but its fractions being aliquot parts of the troy pound, the calculation for real use is very easy: as the troy pound contains 5760 grs. the carat corresponds with 240 grs. or 10 dwt. the assay grain or 4th of a carat with 60 troy grains, and the assay quarter grain with 15 troy grains. To which report, when the assayer has separated the gold (4 oz. for example) he adds *4 oz. gold in a lb. troy.* Whereas in gold parting he takes two equal assay pieces, treats one as a silver assay, and the other as a gold assay, to find the absolute quantity of each metal, after which the report is first made on the gold singly, to which is added the report of the silver separately. Thus if he finds 4 oz. of gold and 3 oz. of silver, he reports *worse 14 carats*, (2 carats being equivalent to an assay ounce, and consequently the 4 oz. of gold equal to 8 carats, which subtracted from 22 carats, the gold standard, leaves 14) to which report he adds *fine silver 3 oz.* But when the mixed metal contains more than half alloy, it is called *metal for gold and silver*, and the absolute quantity of each reported separately.

The assay pound, or integer, is divided in a different manner in several parts of Europe. In France before the late alteration of weights the gold assay was divided into 24 carats, and the carat subdivided into 32 parts, making an ultimate division of 768 parts. The silver assay pound was divided into 12 deniers, and the denier into 24 grains, making 288 grains in the pound.

The Cologne assay weights, used in most parts of Germany, are the following. For gold the

integer, here called a *mark*, is divided into 24 carats, and each carat into 12 grains, making 288 ultimate divisions. For silver, the mark is divided into 16 loths, and the loth into 18 grains, also making 288 subdivisions.

The Chinese use the decimal division for gold as well as silver. The integer contains 100 *touches*, and the simple use of the touchstone will enable the expertest dealers to ascertain with much accuracy, to the $\frac{1}{2}$ touch or 200th of the integer.

The French have of late years adopted the decimal method, consistently with their general system of decimal numeration. The integer for assaying (both gold and silver) is the *gramme*, equivalent to about $15\frac{1}{2}$ troy grains, and the assay subdivisions are the same as those established for the gramme, being tenths, hundredths, and thousandths.

It remains to give the proportions of lead to the estimated alloy of fine metal necessary to be added for cupellation. The most authentic documents for this purpose are probably the very careful experiments of Messrs. Tillet, Hellot, and Macquer, which were the basis of a regulation subsequently adopted by an edict of the late French government.

Copper, the usual alloy of the fine metals, when taken singly is found to require from ten to fourteen times its weight of lead for complete scorification on the cupel. Now all admixtures of fine metal tend to protect the copper from the action of the litharge, and the more obstinately, the greater the proportion of fine metal. So that copper with three times its weight of silver (or 9 oz. fine) requires 40 times as much lead as copper, with 11 parts of silver requires 72 of lead, and the like in an encreasing ratio. The following is the table of the proportions of lead required to different alloys of copper, of which a few points are founded on the above-mentioned experiments, and the rest filled up according to the estimated ratio of encrease (being multiples of the assay integer 24, in arithmetical progression.) In the three first columns is shewn the absolute encrease of the quantity of lead in alloys of decreasing fineness: in the three last columns will be seen the gradual diminution of the protecting power of fine metal against scorification, in proportion to the encrease of alloy shewn by the decreasing quantity of lead required for the same weight of copper, under different mixtures.

TABLE.

Silver.	Copper.	Lead.	Ratio of encrease.	Copper.	Silver.	Lead.
23 with 1 requires		96	(= 4 × 24)	and hence 1 with 23 requires		96
22 — 2 —		144	(= 6 × 24)	1 — 11 —		72
20 — 4 —		192	(= 8 × 24)	1 — 5 —		48
18 — 6 —		240	(= 10 × 24)	1 — 3 —		40
16 — 8 —		288	(= 12 × 24)	1 — 2 —		36
14 — 10 —		336	(= 14 × 24)	1 — 1½ —		33
12 — 12 —		384	(= 16 × 24)	1 — 1 —		32
10 — 14 —		432	(= 18 × 24)	1 — ¾ —		30 ×
8 — 16 —		480	(= 20 × 24)	1 — ½ —		30
6 — 18 —		528	(= 22 × 24)	1 — ⅓ —		29 ×
4 — 20 —		576	(= 24 × 24)	1 — ⅖ —		28 ×
2 — 22 —		624	(= 26 × 24)	1 — ⅑ —		28 ×

It should be remarked however, that many assayers of good authority use proportions of lead to alloy considerably different from the above table, and the whole of the numbers here given may be considered as rather high in regard to the quantity of lead.

The German assayers observe the following rules.^b

Copper.	Silver.	Lead.
1. with 30 requires		128
1 — 15 —		96
1 — 7 —		64
1 — 4 —		56
1 — 3 —		40
1 — 1 —		30
1 — ⅓ —		20
1 — ⅕ —		17

The proportions of lead required for gold assaying are nearly the same as for silver.

Assays of alloys of Platina.

On account of the great specific gravity of platina, it has sometimes been fraudulently employed as an alloy for gold, and being equally unoxidable by lead as gold and silver, it remains in the assay button after cupellation. It is not difficult however to detect this metal even in very small admixtures, and by the following marks. Gold alloyed with so little as 1 per cent of platina, and cupelled in the usual way with 3 parts of silver, differs from gold and silver alone.

1. In requiring a much greater heat for complete fusion of the button, especially at the last when all the lead is worked off, otherwise the button remains flat, like a piece of money, and its surface knotty.

2. Even when the button is well fused, its edges are much thicker and more rounded than in common gold assays, its colour duller and

tending to yellow, and especially it appears remarkably and entirely crystallized on its surface. This power of platina in giving a decided crystalline form to the gold or silver alloys in which it enters, is very characteristic.

3. In the cupellation, as soon as the last portions of lead are worked off, the button appears somewhat pasty, is scarcely iridescent, and especially it does not *lighten* or assume suddenly a brilliant metallic look, but remains dull and tarnished.

These appearances encrease with the quantity of platina in the alloy, but when it amounts to about 10 per cent. the colour of the alloy is so debased and whitened as readily to be distinguished from that of pure or standard gold, by simple inspection.

Silver is seldom alloyed with platina intentionally, the price of the two metals being so nearly the same as not to make it worth while as a fraud. When the platina is not more than 5 per cent. of the alloy, it works easily on the cupel, but the *lightning* is less observable than in a button of pure silver. But the remarkable property of crystallizing is still more conspicuous here than in the compound alloy of gold silver and platina, and the button is besides of a duller white, with somewhat of yellow. When the platina amounts to a quarter of the alloy, the button on the cupel flattens and becomes pasty, even before all the lead is run off; its surface becomes full of knobs, which by help of a glass appear clusters of crystalline points, and its colour is grey and tarnished.

The action of nitrous acid on the alloys of platina is very remarkable. By itself platina is insoluble in this acid as gold is, and an alloy of these two metals equally resists its action. But when silver enters into the mixture in the

same proportion as for parting (that is about $2\frac{1}{2}$ or 3 times the weight of the gold and platina) and when the platina is not more than about a tenth of the gold, the platina is totally soluble in nitrous acid, together with the silver, and the gold alone remains untouched.

On the other hand when an alloy of silver and platina alone is treated with nitrous acid, the silver dissolves as usual, but the liquor soon becomes muddy, with a very fine bulky black precipitate, which continues encreasing till all the silver is dissolved, and when collected is found to be entirely platina, comminuted by the acid, but scarcely changed in any other respect. A part of the platina however remains in perfect solution, for on adding to the liquor, separated from the black precipitate, some muriatic acid, white luna cornea falls down, after which carbonat of potash will throw down a green coagulum, which is oxyd of platina.ⁱ The above effect of nitrous acid will therefore detect an alloy of silver and platina.

Gold alloyed with platina may be entirely purified (as we have just mentioned) by the process of parting with aqua-fortis, the alloy being as usual previously mixed with two or three times its weight of silver. Some peculiar circumstances are required in the operation. The mixed metal being laminated very thin and rolled into a spiral cornet, a weak acid is first added and boiled for some time. If the platina is above 2 per cent of the gold, the acid assumes a straw colour,^a which deepens in proportion to the platina, and at the same time the cornets take a brownish green. A stronger acid is then added and boiled three times successively, to detach the last portions of platina, which are with difficulty separated, and by a magnifying glass may be seen adhering in minute grains to the surface of the gold cornet. Thus by laminating very fine, and by using the acid liberally, and long boiling, all the platina may be separated at one operation, when it does not exceed a tenth of the gold, and above that proportion the colour of the gold is so much debased, and the appearances on cupellation are so striking, that the fraud can hardly escape an experienced eye. Even if more than a tenth of the gold alloy, the platina may still be separated very completely by parting, but in that case more silver must be added, which will reduce the proportion of gold so much, that after the action of the acid the cornet can hardly be annealed without breaking down and losing its form.

For further particulars concerning the weights used by Assayers in different countries see Appendix: article WEIGHTS and MEASURES.

ASTRINGENT (*Vegetable*). Till the later experiments on vegetable substances had shewn the important distinctions between the tanning principle, and the acid, which from its being first extracted from galls has been termed the *Gallic*, that part of vegetables which has the power of tanning leather, and that which strikes a deep inky black with the salts of iron, were both confounded under the general term *astringent principle*, taken from the sensible quality of astringency to the tongue. They are now found to be totally distinct, and will be described respectively under the articles TANNIN and GALLIC ACID.

ATHANOR. A species of furnace much used by the antient chemists, but now mostly laid aside. (*See in the Appendix Chemical Apparatus.*)

ATMOSPHERIC AIR. *Gas atmospherique*, Fr. *Atmosphärische luft*, Germ.

Atmospheric air is an elastic invifible fluid, of the specific gravity of .001204, at the temperature of 60° Fahr. the barometrical pressure being equal to 29.5.^a A cubic inch of air weighs 0.304 grains, a cubic foot 5253. grains, and it is 830 times lighter than water. Being elastic, its specific gravity or density depends upon, and is in proportion to, the force by which it is compressed, therefore the density of the air above the surface of the earth decreases in a geometrical ratio, as the height increases in an arithmetical one. If at the surface of the earth the density of the air corresponds to 30 inches of barometrical pressure, then at

feet.	inches.
1000 the mercury is	28.91
2000 —————	27.86
3000 —————	26.85
4000 —————	25.87
5000 —————	24.93
1 mile —————	24.67
2 —————	20.29
3 —————	16.68
4 —————	13.72
5 —————	11.28
10 —————	4.24
15 —————	1.60
20 —————	0.95 ^b

Air, like all other bodies, is expanded by heat, and the quantity of expansion being very considerable, it is of importance to the accuracy of chemical experiments on this substance to

ⁱ Tillet. ^a Vauquelin, Tillet. ^a Fletcher, in Nicholson's Journ. iv. p. 35. ^b Rees's Cycloped. art. Barometer.

have it ascertained with precision. From the nearly concurring results of Gen. Roy's experiments, and those of Sir G. Shuckburg, it appears that the air measures in bulk $\frac{1}{466}$ for every degree of Fahrenheit between 32° and 72° . Mr. Dalton finds^c that 1000 parts of air at the usual barometrical pressure, and 55° of temperature, dilate to 1325 when raised to 212° Fahr. he is also of opinion that the ratio of dilatation is a gradually decreasing one as the temperature descends.

The colour of the air when free from clouds is a blue, of greater or less intensity. Near the surface of the earth it is diluted by the white rays of light that are reflected from the aqueous vapour that is constantly floating in the lower regions of the atmosphere, but in proportion as the observer is elevated above these vapours, the colour of the sky assumes a more intense blue. Saussure^d observes that the sky from the summit of Mont-Blanc appeared of a deep almost black prussian blue.

The chemical properties of atmospheric air were but little attended to till about thirty years ago; but before we give an account of the modern discoveries on this subject, it will be right to take a short view of what had been previously done by two eminent philosophers, Boyle and Mayow; the latter of whom has been consigned to unmerited neglect for more than a century, although the most profound observer of his time.

The apparatus which Boyle^e made use of in his experiments was the air-pump, an instrument with all its modern improvements but very imperfectly fitted for the chemical examination of elastic fluids, and at that time a huge cumbersome machine, worked by the constant labour of two men, and imbibing air at every pore. By the help of this instrument, Boyle ascertained that the presence of air was essential to the support of flame and animal life, a candle being extinguished, and various small land animals, and even fish in water, being killed by being placed in an exhausted receiver. He also shewed that the same effects take place, but more slowly in a confined portion of atmospheric air, and that the death of animals in this situation was not owing to the heated exhalations from their own bodies, since the same effects took place when the apparatus was transferred to a frigorific mixture. He proved besides that animals live longer in a given bulk of condensed than of common air. He did not believe how-

ever that any absorption of air took place in respiration, or that the pure atmosphere was a compound substance.

Mayow published his Medico-physical tracts a few years after Boyle, and a century before the discovery of oxygen gas by Priestley and Scheele. This able, though much neglected philosopher, commenced his investigations into the nature of atmospheric air by the invention of a proper apparatus; for this purpose, rejecting the use of the air-pump, he made choice of glass jars inverted in water, as the best method of confining the gasses that were submitted to examination. Setting out from the facts discovered by Boyle, he argues that since a candle is extinguished much sooner in an exhausted receiver than in the same when filled with air, there must be something in the atmosphere necessary to the continuance of flame. This is further proved, says he, from the impossibility of kindling a combustible body *in vacuo*, by the concentrated rays of the sun, or by any other means. Having established this first position, he proceeds to infer that it is not the whole of the air which is capable of supporting flame, because a candle goes out in confined air, while the greatest part of the air is as yet unconsumed. Also since sulphur when mixed with nitre becomes capable of inflammation *in vacuo*, it follows that nitre and air contain some substance in common to which this property is to be attributed. This substance he denominates *igneo-aerial particles* (particulæ igneo-aeræ). He next determined the analogy between flame and animal life, and shewed that each depended for its continuance on a supply of igneo-aerial particles. That there was a real consumption of air in combustion and respiration, he proved by the rise of water in the jars in which a live animal or a lighted candle was confined; and that the diminution was owing to the abstraction of the igneo-aerial part, appeared from the inability of the residue to support animal life. With regard to the relative proportions of the atmosphere, he only observed that air rendered unfit for combustion by the breathing of an animal, lost about one-fourteenth of its bulk; at the same time remarking that there was probably only a part of the igneo-aerial portion of the air consumed. But Mayow never obtained the igneo-aerial particles in a separate state, and therefore was unable to confirm his analysis of atmospherical air by the synthetical proof.^f

The next advance in the decomposition of

^c Manchester Mena. vol. v. p. 599.

^d Voyages dans les Alpes, vol. iv. § 2009.

^e Boyles Works, v. ii.

^f Mayow, Tractatus quinque medico-physici.

atmospherical air was made by Dr. Priestley.^g This philosopher having inclosed some *mercurial precipitate per se*, in a jar filled with mercury, and inverted over the same, procured from it by means of heat, a quantity of gas, in which a candle burnt with a dazzling and enlarged flame: the coincidence of this with the effect produced by dephlogisticated nitrous gas in the same circumstances, as had been before observed by him, induced him to believe that there was some common principle in nitrous acid and atmospherical air, and this suspicion was still further confirmed by the discovery that common *red precipitate*, which is prepared by means of nitrous acid, yielded dephlogisticated air in the same manner as the precipitate *per se*. Hence he concluded that the atmosphere consisted of this pure, or vital, or dephlogisticated air, mixed with a variable portion of phlogiston.

While Dr. Priestley was making these experiments, the acute and accurate Scheele^h was pursuing the same course of investigation, though in a different manner. He observed that phosphorus, and the watery solutions of the earthy and alkaline sulphurets, when confined with a given quantity of air, had the property of absorbing about a third or a fourth of its bulk, and left the remainder unable any longer to support flame or animal life, which in consequence was called by him *foul air*. By exposing nitre, the black oxyd of manganese, and some other substances to a red heat, he obtained from them a quantity of the same kind of air as Dr. Priestley's dephlogisticated, but which was called by him *pure air*; and this when mixed in the proportion of one part to two of foul air, formed an elastic fluid, which could not be distinguished from atmospherical air. Scheele therefore concluded that the atmosphere is composed of two different substances, pure air and foul air, or according to the modern nomenclature, of oxygen and azot, in the proportion of one of the former to two of the latter.

The experiments of Scheele were soon confirmed by the conclusions of Lavoisier,ⁱ from somewhat different premises. He confined a few ounces of mercury, and about 50 cubical inches of atmospherical air, in a proper glass apparatus, and exposed the mercury for twelve days, to a heat nearly equal to that of ebullition; during this period 45 grains of red oxyd of mercury were produced, between seven and eight inches of the air disappeared, and the remainder

was incapable of supporting flame and animal life. The 45 grains of red oxyd being then heated in a very minute retort, were wholly decomposed into 41 grains of running mercury, and seven or eight cubic inches of pure oxygen gas; finally this gas being mixed with the residual air in the first part of the experiment, produced a compound, possessing nearly the same power of supporting combustion and respiration as atmospherical air. Hence it appears that atmospherical air consists of 16 per cent. of oxygen and 84 of azot.

Various instruments called EUDIOMETERS (which see) have since been invented for ascertaining in a commodious and accurate way the quantities of oxygen and azot in common air, several unexpected sources of error have been discovered and obviated, and by the latest and most unexceptionable experiments, the relative proportions of oxygen and azot appear to be 22 of the former and 78 of the latter,^k in bulk, or 26 oxygen and 74 azot, if estimated by weight. Concurring experiments also have been made with the greatest care in Egypt and every part of Europe, from which the general conclusion is, that neither climate nor temperature, nor distance above the surface of the earth, produce the smallest variation in the relative quantities of these gasses, which compose so large a proportion of the whole atmosphere.

The only remaining substance, except water, which has hitherto been detected in common air, is carbonic acid: it is found not only in that stratum which immediately rests upon the surface of the earth, where from its superior specific gravity it might be expected to continue, but was found by Saussure to enter into the composition of the air at the summit of Mont-Blanc, about 5000 yards above the level of the sea.^l The proportion of this gas to the other two already mentioned, has not been determined with the desired accuracy; according to Humboldt it varies from 5 to 1 per cent. but the general average, from the experiments of other chemists, does not exceed 2 per cent. and it is probable that this ratio is nearest to the truth.

ATMOSPHERICAL *Mephitis*. A term given by some to the air now called Azot.

ATTRACTION (*Chemical*.) See AFFINITY.

AUGITE. *Augit*, Werner. *Pyroxène*, Haüy.^m

The colour of this mineral is generally a dark green, passing sometimes into leek-green and liver brown. It occurs disseminated in small irregular grains or crystallized. The primitive

^g Experiments on Air.

^h Scheele, on Air and Fire.

ⁱ Lavoisier's Elements of Chemistry, p. 80.

^k Thompson's Chim. 2d edit. vol. iii.

^l Voyages sur les Alpes.

^m Emmerling, Jameson, Haüy, Brochant.

form of the mineral is an oblique rhomboidal prism, of 92° and 88° divisible parallel to the sides of the prism, and also in the direction of the long diagonal of the base into two oblique triangular prisms.

The chief varieties of crystallization to which it is subject are the following.

1. A short rectangular six-sided prism (perihexaédre of Haüy.)
2. The same terminated by dihedral summits (bisunitaire of Haüy.)
3. An octahedral prism, formed by bevilling the acute edges of the six-sided prism (perioctaédre of Haüy.)
4. The preceding terminated by dihedral summits (triunitaire of Haüy.)
5. The preceding with the summit bevilled (sexoctonal of Haüy.)
6. The same as var. 4. having the acute solid angle of the summit replaced by a triangular horizontal facet (soustractive of Haüy.)
7. Two or more crystals crossing each other (hemitrope of Haüy.)

The crystals are in general very small, the largest, about an inch and a half in length, have been found at Arendahl, in Norway.

The fracture of augite is uneven, passing into conchoidal, or foliated: its lustre is resinous and shining, approaching in some specimens to brilliant. It is translucent, the conchoidal varieties however are often semitransparent. It is sufficiently hard to scratch glass. Sp. gr. 3.22 to 3.47. It gives a green streak.

In small pieces it is difficultly fusible before the blowpipe into a black enamel. The constituent parts of the augite from Etna, according to the analysis of Vauquelin, are

52.	silica,
13.2	lime,
3.33	alumina,
10.	magnesia,
14.66	oxyd of iron,
2.	— of manganese.
95.19	
4.81	loss
100.	

Augite is distinguished from Olivine by its darker colour, greater hardness and crystalline form; from hornblende in being diagonally divisible into triangular prisms, and in being much less fusible; from tourmaline in not being electric by heat and being more difficultly fusible.

It is found in basalt, often accompanied by olivine, in Bohemia, Transilvania, Hesse, Saxony, Auvergne, Scotland and Norway. It is also found imbedded in the lavas of Etna and Vesuvius, and when in this situation is not unfrequently of a grey or white colour, a somewhat harsh feel, little or no lustre, soft and brittle, by having been exposed to the action of the fire: in some specimens these changes are only superficial, the nucleus exhibiting the genuine characters of augite, as above described.

AURUM FULMINANS. A precipitate of Gold from its nitro-muriatic solution by ammonia, which possesses a most remarkable explosive property.

AURUM GRAPHICUM, PROBLEMATICUM. See TELLURIUM.

AURUM MUSIVUM. A golden-coloured sulphuret of Tin.

AVENTURINE. See QUARTZ.

AVIGNON-BERRY. The berries of the *Rhamnus Infectorius* (Nerprun des Teinturiers,) are used considerably in the middle and south of France, to give a yellow dye. They are gathered unripe, bruised, steeped and then boiled in water, mixed with the ashes of vine stalks to give a body, and then passed through fine linen. The colour thus prepared is called *fil de grain*. It is a fine yellow chiefly used in silk-dyeing, but is very fugitive especially in the sun. The plant grows abundantly about Avignon, and in the south of France.

AXINITE. See THUMERSTEIN.

AZOT or Nitrogen. *Stickgas*, Germ.

This gas (the *phlogisticated air* of Priestley) forms the unrespirable part of atmospheric air, and exists in it in the proportion of about 78 per cent. estimated by bulk, or 74 per cent. by weight.

The properties, by which this air was first distinguished, were principally negative, and in direct opposition to those of oxygen, the other constituent of the atmosphere; the latter supporting combustion in an eminent degree, maintaining animal respiration, oxydating metals, &c. whilst the former was found to be immediately fatal to animals immersed in it (whence its name *azot*), to extinguish flame instantly, and to produce no change on combustible bodies immersed in it.

Azot is readily procured from atmospheric air by all the following processes, which absorb its oxygenous portion, and which are more fully detailed under the article EUDIOMETRY. If iron filings and sulphur, in equal parts, are

worked up into a paste with water, and introduced under a jar of common air confined over water, a gradual absorption of the oxygen takes place, which is complete in about two days, and the residue is azotic gas in great purity. After the diminution of air has ceased, the iron filings and sulphur should be removed, otherwise some sulphuretted hydrogen will be evolved, and the azotic gas should in all cases be agitated with lime water or caustic alkali, to absorb any carbonic acid with which it may be mixed, after which the azot is pure.

Azot may be instantly obtained from common air by adding just so much pure nitrous gas as will destroy the oxygen and no more, or better, by agitating common air with a solution of sulphat of iron saturated with nitrous gas. The residue is then very pure azot. Or it may be obtained by another eudiometric process, namely, by abstracting the oxygen from common air by means of phosphorus. In this case however the remaining azot dissolves a small portion of the phosphorus, sufficient to render it luminous on mixing with it the smallest portion of oxygen.

Azot is a constituent part of almost all ANIMAL substances, and is the cause of the production of *ammonia*, when they are heated to disorganization or during putrefaction. It forms at the same time a constituent part of this alkali.

The production of azot in the form of gas from animal matter is shewn in the following way. Put some of the lean of any meat (beef for example) into a glass vessel with a bent tube, pour thereon some very dilute nitric acid, and apply a heat of about 100°. Bubbles of gas will slowly arise, which when collected and examined are found to be pure azot. The azot in this case does not proceed from the nitric acid, as this appears to be able to saturate as much alkali after the process as before, and hence it seems only to effect a decomposition of the meat, though in a way that is not very apparent.

Azot is however a constituent of the NITRIC acid, as was first shewn by the beautiful and decisive experiments of Mr. Cavendish, who by means of the electric spark combined azotic and oxygenous gases, and the result of this union was found to be the nitric acid. By this most important discovery it is explained how the putrefaction of animal matters in certain stages is so favourable for the production of nitre, with many other phenomena to be described in their place. From this combination of azot, the term *nitrogen* (or the base of nitric acid) has been adopted by some chemists, and is certainly preferable to the other, which only implies the

general property of destroying life, a property possessed in a greater or less degree by every gaseous body in nature, oxygen and some of its combinations excepted. Azot in its different stages of oxydation becomes *nitrous oxyd*, *nitrous gas*, and *nitric acid*, all very interesting substances in their chemical properties.

Azot has hitherto never been decomposed (all the supposed experiments to this purpose having been found fallacious), and hence it must be considered as a simple body. When pure it is lighter than common air nearly in the proportion of 98 to 100, so that if a cubic inch of the former at 60 therm. and 29.5° bar. weighs .304 of a grain, a cubic inch of azot, under the same circumstances, will weigh .2994 of a grain, and its specific gravity is about .001199.

Water absorbs not quite $\frac{1}{6}$ of its bulk of this gas assisted by agitation, Mr. W. Henry having found that at 60° 100 measures of water could take up no more than 1.47 measures. All common experiments therefore may be made with this gas over water, without risk of much inaccuracy. This solution of azot in water shews neither acid nor alkaline properties, nor does azot by itself, or in simple combination with water or any other fluid, give any smell, taste, or sensible quality.

In chemical analysis azot is detected chiefly by its negative properties. A gas may be concluded to be azot which instantly extinguishes a taper immersed in it, and at the same time is not sensibly absorbed by water or liquid alkali, nor renders lime-water turbid; which does not blacken the solutions of lead or silver; which mixes with oxygen in any proportion without diminution or the production of red fumes; and when so mixed, does not explode by the contact of a lighted body, but allows the burning substance to consume quietly in it, and as long as in common air, when the proportions of it to oxygen in the mixture have been taken at about 78 to 22.

The affinities of azot are unknown.

AZOT Gaseous Oxyd of. See NITROUS OXYD.

AZURE. *Azure* or *azure blue* is a term applied to two very different substances. Formerly it was used for the fine blue colour prepared from *ultramarine* or *lapis lazuli*, but now more commonly it is applied to the deep blue glass of cobalt, called also *smalt*, and in Saxony *zaffre*. In masses the blue glass is named *smalt*, but when ground to fine powder, it is called by the French *bleu d'azur*. It is used as a colour, and in enamel painting, and also mixed with starch for domestic purposes. See COBALT.

B

BALLOON. A globular glass vessel with a narrow neck, a common article of *chemical apparatus*. (See the *Appendix*.)

BALNEUM. See BATH.

BALSAM (Vegetable). The term balsam was antiently applied to any strong scented natural vegetable resin of about the fluidity of treacle, inflammable, not miscible with water without addition, and supposed to be possessed of many medicinal virtues. All the turpentine, the Peruvian balsam, Copaiba balsam, &c. are examples of the natural balsams. Besides, many medicines compounded of various resins or oils, and brought to this consistence, obtained the name of balsam.

Latterly however the term has been restricted to those resins which contain the benzoic acid. Of these only three are commonly known, the Gum Benzoin, *Styrax* and Balsam of *Tolu* (which see).

BARBADOES TAR. See BITUMEN.

BARILLA. The impure CARBONAT of Soda in the state in which it is imported from different parts of Europe.

BARKS of Trees. See WOOD.

BAROLITE. See WITHERITE.

BAROSELENITE. See HEAVY SPAR.

BARYTES. *Baryte*, Fr. *Schwererde*, Germ.

This earth is never found pure in nature, but always in combination either with the sulphuric acid, forming the native SULPHAT of Barytes or HEAVY SPAR; or combined with the carbonic acid into CARBONAT of Barytes or WITHERITE.

Pure barytes is always prepared either directly from the native carbonat, or from the artificial carbonat produced by a previous decomposition of the sulphat of barytes. The latter is the most frequent, as the sulphat is very generally diffused over the globe, whereas the native carbonat has been only found hitherto in England and in Siberia.

Sulphat of barytes is decomposed by several processes, all of which deserve notice.

§ 1. Mix sulphat of barytes in fine powder, with not less than twice (and better three times) its weight of dry carbonat of potash, and heat the mixture moderately red for at least half an hour, in an earthen or silver crucible. Pour out the melted mass, and when cold, powder it, and boil with water repeatedly, till the water no longer tastes saline. The soluble part of this mass is sulphat of potash, arising from the

decomposed sulphat of barytes, with some undecomposed carbonat of potash. A white insoluble residue chiefly carbonat of barytes remains, from which the pure barytes is prepared in the way to be presently mentioned.

§ 2. Mix finely powdered sulphat of barytes with at least twice its weight of carbonat of potash,^a and five or six of water, and boil in a metal, earthen, or glass vessel for about an hour, adding water occasionally to supply the loss by evaporation. Pour off the liquor, which is chiefly sulphat of potash, and wash the residue as before. It consists of carbonat of barytes, mixed with undecomposed sulphat, in greater quantity than by § 1. A repetition of the process (the carbonat of barytes being first separated from the residue by muriatic or nitric acid) will further decompose the remaining barytic sulphat, but with much more difficulty than by fusion.

§ 3. Mix sulphat of barytes with about a sixth of its weight of powdered charcoal, and calcine with a moderate red heat for half an hour in an earthen (not silver) crucible. By this the sulphat is chiefly converted to a sulphuret of barytes, easily soluble in water. Dissolve, and add to the clear watery solution, which is sulphuret of barytes, liquid carbonated soda, as long as any white precipitate falls down. This precipitate is carbonat of barytes, the liquor is now sulphuret of soda, which is useful for many purposes of the laboratory. If the solution of sulphuret of barytes is concentrated when hot, it crystallizes on cooling, and therefore the solution should be so dilute as not to crystallize.

Another method is to add to the liquid sulphuret prepared as above mentioned, some concentrated muriatic acid. This unites with the barytes and remains in solution, whilst part of the sulphur falls to the bottom, and part flies off in a most copious emission of sulphuretted hydrogen, which follows the addition of the acid. The muriated barytes may then be decomposed by a carbonated alkali, which will leave a pure carbonated barytes.

§ 4. La Grange^b has described another method of obtaining muriated barytes, from which the carbonat may be procured as above. This is by muriated lime and sulphat of barytes, which decompose each other mutually. For this, take the residue from the distillation of muriated

^a Klaproth's Essays, vol. i.

^b Ann. Chim. tom. 47.

ammonia (which is muriated lime with excess of earth), lixivate it and evaporate the clear liquid to dryness. It is then saturated muriated lime (and of course any other soluble muriated lime will answer as well) which reduce to powder, and mix with its own weight of sulphat of barytes. Project the mixture by spoonfuls into a red-hot crucible, and let the whole remain in quiet fusion for a few minutes. Then pour it out while hot, and it will be a grey or often slate-coloured, hard, sonorous mass, very deliquescent. Dissolve it in about six times its weight of boiling water, and filter. Evaporate the clear solution till a pellicle appears on the surface, then set it by to crystallize. By cooling, very fine large crystals of muriated barytes will be formed, which will be very distinguishable by their size and whiteness. Take them out, evaporate further to obtain a second crop of crystals of the same, then redissolve the whole, and crystallize a second time by evaporation and cooling. A third crystallization is perhaps required to separate all the sulphat and undecomposed remainder of muriated lime.

This process appears very good, but is more particularly calculated for those cases where only the muriated barytes is wanted, and not the carbonat by its means.

The carbonat of barytes thus artificially obtained, as well the native carbonat, is converted to pure barytes in two ways, first, by calcination, secondly, by being dissolved in the nitric acid, and the nitrat afterwards heated strongly, till all the acid is driven off. In either case the barytes will be pure.

1. A great difference is observed between the natural and artificial carbonats in the power of retaining their carbonic acid when strongly heated. The artificial yields its carbonic acid and calcines nearly with the same ease as limestone, but the natural can scarcely by any moderate heat be made to give out its carbonic acid. Another inconvenience too arises in the calcination, namely, that barytes acts so powerfully as a flux upon clay and all other earths, that when strongly heated, in proportion as it loses its carbonic acid, it dissolves the clay crucible, and the whole runs together without much difficulty into a hard greenish glass. The native carbonat, heated most intensely in a platina crucible for many hours, at 136° of Wedgwood, was found by Klaproth to have lost only half its carbonic acid, and to adhere so strongly to the crucible as scarcely to be detached by boiling water, in which pure barytes

is readily soluble. In a charcoal crucible the native carbonat heated most intensely was found by the same eminent chemist to be never entirely calcined, but always to have penetrated the substance of the charcoal and collected at the bottom in a semifused mass.

It is therefore only the artificial carbonat which can be calcined without addition; but Pelletier^d has discovered an easy method by which both the natural and artificial may be totally and speedily deprived of carbonic acid. Mix the carbonat of barytes with a tenth of its weight of charcoal powder, make it up into a lump with paste or starch, or any mucilage, drop it into a crucible lined with charcoal, cover it with charcoal powder, and lute a cover to the crucible. Heat the whole very strongly for an hour (probably half the time would suffice), and when cold the lump will be found to have retained its form, and to be white, friable, not vitrified, and entirely soluble in warm water, excepting a small remaining portion of charcoal. It is now pure barytes. By this ingenious method (which will apply with advantage to all the earthy carbonats) the barytes is prevented from acting on the crucible, and the carbonic acid escapes chiefly in the form of *gaseous oxyd of CARBON*.

2. The other method of preparing pure barytes is by calcination of the nitrat of barytes. The native carbonat is scarcely acted on by concentrated nitric acid, but when considerably diluted the solution goes on rapidly with extrication of carbonic acid gas, and a clear saturated nitrat is obtained. The artificial carbonat is directly dissolved in this acid with copious effervescence, but if absolute purity is required some precautions are necessary, as native sulphat of barytes generally contains a small admixture of strontian, of oxyd of iron, and of silica. These all remain in the residue of § 1. which therefore consists chiefly of carbonat of barytes with the above impurities in small quantity, together with any sulphat of barytes that may remain undecomposed. To this residue first add acetic acid,^e which dissolves out only the carbonats of barytes and strontian, and the iron. Evaporate this solution till it is quite of a syrupy consistence, then add concentrated nitric acid. A copious deposition of small crystals of pure nitrated barytes now appears, leaving the strontian and iron in solution, the reason of which is, that the barytic nitrat is much less soluble than the nitrats of strontian or iron, and therefore cannot be held in solution in so small a

^c Klaproth.

^d Memoires, tom. 2.

^e Lampadius's Handb. zur Ch. Analyse.

bulk of liquid. Collect these crystals of nitrated barytes, and wash them with a little cold water, and they are now pure.

The nitrated barytes, either crystallized or merely evaporated to dryness (according as more or less nicety is required in the preparation) is then to be heated in a porcelain retort, or earthen crucible slightly covered, to prevent any of the fuel from falling in. It presently melts, swells up and gives out much azotic and oxygen gas, with a little nitrous vapour. The heat is to be continued at a moderate redness, till no more vapour or gas of any kind arises, when the residue will be found to be pure barytes, in the form of a grey somewhat porous mass, and if the heat has been too strong, partly fused with and adhering to the sides of the crucible. A considerable time is required to destroy all the nitric acid, when no more heat is used than the crucible will allow of, but a platina crucible is preferable, as the heat may be given freely without danger of vitrifying the barytes, which would render it insoluble in water.

Barytes prepared in either of the above methods has the following properties: its taste is like that of lime, but much more acrid and caustic; and it changes the vegetable colours as the alkalies do. When a little water is added it absorbs it with great avidity, giving out much heat, and becomes a stiff paste, which soon solidifies and adheres strongly to glass.^f A further quantity of water changes it to a bulky white powder, which readily dissolves, especially when heated, and on cooling it has the remarkable property of crystallizing in clusters of transparent needles. No other earth but barytes and strontian can be thus artificially crystallized.

Barytes is extremely soluble in water: when boiling, water dissolves more than half its weight, the greater part of which crystallizes on cooling, for cold water dissolves only a twenty-fifth of its weight. Slowly cooled, the crystals are fine transparent prisms.

Barytes when heated on charcoal, by the blowpipe becomes hard and semivitrified in texture, and is scarcely again soluble in water. It seems to return by this process partly to the state of carbonat, gaining carbonic acid from the flame of the lamp. When the blowpipe is urged with oxygen gas, barytes readily melts into a white enamel-like globule.

Barytic water (or a solution of barytes in water) resembles limewater in absorbing carbonic acid from the atmosphere, or from any gas with which it may be in contact; only this

takes place with much greater rapidity in the barytic solution, being much more concentrated than the lime-water. Hence merely on pouring barytic water slowly from one vessel to another, it becomes slightly turbid. The barytes as it becomes carbonated falls to the bottom as a white powder. Barytes is soluble in alcohol, but with difficulty unless assisted by heat. The oxalic, citric, phosphoric and malic acids give crystalline precipitates with saturated barytic water, which are resolvable with a slight excess of the same acid. Most of the metallic solutions are decomposed by barytic water, and the precipitated oxyds of silver and lead are again dissolved by an excess of the barytes.^g

Barytes, its carbonat, both native and artificial, and all its soluble salts are violently poisonous.

The combinations of barytes with the acids are described under the respective acids.

The affinity of barytes with the earths very strongly resembles that of the fixed alkalies in several important particulars. The powerful action of barytes as a flux in a red heat has been already mentioned, and the ease with which clay crucibles are corroded by it. The two following experiments shew this combination very strikingly.^h Three parts of pure barytes were mixed with one of flint, and heated violently for an hour in a platina crucible. When taken out it was a homogeneous, porous, friable mass, somewhat green, tasting sweetish, and not heating when flaked with water, as pure barytes does. It dissolved wholly in nitrous, muriatic and acetic acid, and gave a curdy precipitate with ammonia, whereas the simple solution of barytes is not disturbed by this alkali. Evaporated, this solution stiffened to a jelly when nearly dry (a sure mark of the presence of flint), and when solid the siliceous earth was left in its proper character. Thus then barytes renders flint entirely soluble in acids, and potash does the same.

2. Nine parts of barytes were mixed with one of pure alumine newly precipitated from its solvent and still wet, and the mixture was boiled for a quarter of an hour with water. This yielded both a clear liquor and an earthy residue. The liquor was only slightly burning to the taste, and though it absorbed carbonic acid from the air, and let fall a white barytic carbonat, it would not crystallize as pure barytes though the quantity of water to the earth was but small. Muriatic acid, only enough to saturate the barytes, gave a flocculent precipitate of alumine, which an excess of the acid redissolved.

^f Vauquelin, An. Ch. 25.

^g Ibid.

^h Ibid. 29.

solved. When saturated with the acid, ammonia gave also a precipitate of alumine. The earthy residue from the first solution was an intimate mixture of alumine and barytes, in which the natural solubility of the latter in water was destroyed by its union with the former. Thus a great excess of barytes over the alumine is requisite to a solution of these earths, which is also shewn by adding hot saturated barytic water to muriat of alumine: the first drops produce a precipitate, which a further addition of barytic water redissolves.

Barytes unites easily with all kinds of oils. If barytic water is added to a solution of soap, an insoluble curd falls down, which is an union of the barytes with the oil of the soap, whilst its alkali remains caustic and uncombined in the liquor. Also when a hot saturated barytic water is boiled with olive oil, a barytic soap is formed, differing however from the alkaline soaps in being insoluble in water.

The fixed alkaline solutions, heated with any of the soft parts of animals, dissolve them, and at the same time cause the evolution of much ammonia. Barytes has the same effect with regard to the production of ammonia, and forms with the animal matter a soft pulp insoluble in water.

Therefore, from these and other striking analogies, barytes (as well as strontian, which agrees with it in most of the above particulars) has been actually classed as an alkali by some chemists, and by others as an *alkaline earth*.

The discovery of strontian is of a much later date than that of barytes, and the resemblance between the two is so very striking in many essential particulars, and so much greater than that which subsists between any two of the other earths, that chemists have taken some pains to establish the separate identity of strontian. The following are some of their most remarkable points of resemblance.

They are both found native, only in the states of sulphat and carbonat. The sulphats are both nearly insoluble in water, and are formed artificially by the union of any other solution of these earths with any salt in which the sulphuric acid enters. Also the sulphats of these earths readily dissolve in strong sulphuric acid, and are both precipitated by the addition of water.¹

The methods above described for the decomposition of sulphat of barytes, apply equally to the sulphat of strontian.

The *native* carbonats are both scarcely calcinable by mere heat, but the artificial carbonats much more readily. They are equally decom-

posed by charcoal. They also act with equal energy as a flux on earthy substances.

The pure earths are both crystallizable from their hot watery solutions, soluble in alcohol, and both exhibit in taste and other chemical properties a very strong resemblance to the fixed alkalies, forming a species of soap with oils, dissolving filix and alumine, and the like. They also attract carbonic acid from every surrounding body with readiness, and in so doing, the earth precipitates totally from its solution in the form of a white carbonat.

The carbonats of each earth are soluble with effervescence in most of the acids, but the native carbonats much less easily than the artificial. Pure ammonia precipitates neither the one nor the other.

On the other hand there is such a decided difference between the two earths in the following essential particulars, that we cannot hesitate to class them as distinct earths.

Barytes and all its salts (except the sulphat which is insoluble in most fluids) are violent poisons, destroying animals by inflaming the stomach and intestines. The corresponding preparations of strontian are quite innocent, and appear to produce no effect whatever in any moderate quantity.^k

Strontian, or any of its salts dissolved in alcohol, give to its flame a beautiful carmine red. The barytic salts on the other hand give only a faint yellow.

The affinity of strontian to acids is less than that of barytes, so that barytes decomposes the strontian salts by simple affinity, and lime, which is weaker than barytes in its affinities, is superior to strontian.

The form, habititudes and solubility of many of the salts of barytes, differ from those of the corresponding strontian salts. In general the barytic salts are much less soluble than the strontian. Barytes however is ten times more soluble in water than strontian.^l Sulphat of barytes is absolutely insoluble in water, sulphat of strontian slightly soluble, especially with a small excess of the acid, and hence the former will shew the presence of sulphuric acid in much minuter quantity than the latter. On the other hand the precipitated oxalat of strontian (formed by oxalic acid and any solution of this earth) cannot be dissolved by an excess of this acid, whereas the oxalat of barytes is resolvable by this method. The nitrat, muriat and acetite or barytes are much less soluble in water than the corresponding strontian salts, and are heavier

¹ Klaproth.

^k Pelletier.

^l Vauquelin.

and more opaque. The little solubility of the nitrated barytes is shewn by its copious precipitation when nitric acid is added to concentrated acetited or muriated barytes, which does not take place with the solutions of strontian. The gallic and malic acids added to barytic water give a precipitate, the former white, the latter greenish. With strontian water no such effect is produced. The muriats shew the most striking difference, and hence this acid is generally resorted to in chemical analysis.

In a mixture of the two muriats, the barytic begins to crystallize in a much more dilute solution than the strontian, and the muriated barytes forms large opaque heavy oblong hexagonal tables, with some varieties; whereas the muriated strontian does not separate till the liquor is of a syrupy consistence, and then produces long slender transparent, light, needle-shaped bundles of crystals, often radiated. This difference cannot be overlooked by the most careless observer.

From what has preceded, the reader will be able to understand the habitudes of barytes when subjected to chemical analysis. The following facts may be of use in analysis, in separating barytes from lime and strontian, the earths with which it is most liable to be mixed.

Pure fluoric acid, or better, fluat of ammonia, quite free from sulphuric acid, will precipitate lime from its solution, but not strontian nor barytes. Barytes may be separated from lime and strontian either by evaporating the mixed muriated solutions, when, as above mentioned, the muriated barytes crystallizes distinctly and separately; or by judiciously adding cold alcohol to the entire contents of the solution evaporated to dryness, which will dissolve out the muriats of lime and strontian, and leave almost the whole of the muriat of barytes; or by adding strong nitric acid to the concentrated solution, which will precipitate the nitrated barytes in crystals, leaving the other two earths in solution. The first of these methods appears the most exact.

It may be added that many chemists have been mistaken in supposing that the PRUSSIC acid was a test for barytes, for the precipitate produced by common prussiat of potash and a barytic solution, has been found to arise only from an admixture of sulphat of potash with the prussiat.

The affinities of barytes are: in the moist way—the sulphuric, oxalic, succinic, fluoric, saccholactic, nitric, muriatic, phosphoric, citric, tartareous, arsenic, benzoic, acetic, boracic, sul-

phureous, carbonic and prussic acids, sulphur and fat oil.

BASALT.^a *Basalt*, Werner. *Basalte*, Brochant.

The colour of basalt is generally greyish black, passing into ash-grey, brownish black and bluish black: the surfaces of its natural divisions are of a greyish ochre colour, which tint is also acquired by the surface of any casual fracture after a short exposure to the weather. It occurs in mass or vesicular. Internally it is dull, though sometimes feebly glimmering, on account of very minute crystals dispersed through its substance. Its fracture is coarse or fine grained uneven, or fine splintery; in large pieces often conchoidal, and sometimes, though very rarely, even and earthy. It is amorphous or tabular, or in columnar angular distinct concretions, from a few inches to two hundred feet in length, either simple or articulated, and the articulations are plain, or formed by the convex end of one piece implanted in the concave end of the next; or finally it is found in globular masses, composed of concentric lamellæ of various sizes, even to two feet or more in diameter. It is opaque, but sometimes feebly translucent on the edges. It gives a light ash-grey streak: is nearly equal in hardness to common glass, but possesses a degree of toughness which renders it very difficult to be broken. Sp. gr. 2.86 to 2.97. It is for the most part attracted by the magnet, and sometimes possesses polarity.

It melts with ease before the blowpipe, without addition, into a black glass. The basalt of the Hassenberg, in Bohemia, has been analysed by Klaproth^b, and that of Staffa by Dr. Kennedy, with the following results.

	Klapr.	Kenn.
Silex - - - - -	44.5	48.
Alumine - - - - -	16.75	16.
Oxyd of iron - - - - -	20.	16.
Oxyd of manganese - - - - -	0.12	0
Lime - - - - -	9.5	9.
Magnesia - - - - -	2.25	0
Soda - - - - -	2.6	4.
Moisture and volat. matter 2.		6.
	97.72	99.

Basalt not unfrequently contains olivine and basaltic hornblende, sometimes felspar, and when verging into Wakke, mica, calcareous spar, calcedony and zeolite.

According to Werner, basalt is confined to the Floetztrap or secondary trapformation. It occurs in vast mountainous beds, mostly of a

^a Widenmann, Emmerling, Brochant, Jameson, Kirwan.

^b Analyt. Ess. v. ii. p. 195.

conical form, in strata, in banks or dykes, and in veins. It is met with in most parts of the world, and almost always accompanies coal: the columnar variety, where the pillars are long and well defined, exhibits a remarkably grand appearance. The small island of Staffa, on the western coast of Scotland, is entirely composed of basaltic pillars, both strait and bending; the Giant's causeway, on the coast of Antrim, in Ireland, is a huge pavement of strait pillars, running to an unknown distance in the sea, and backed by a steep rock, containing numerous ranges of similar columns: the promontory of Fair-head, a little further to the north, exhibits a continued range about a mile in length of columns, 250 feet high, and from ten to twenty in diameter, ^c being the largest yet known.

The uses of basalt are various. From its being tougher and more durable than marble, it was a favourite material with the ancient Egyptian sculptors, many of whose works executed in basalt are at the present day in as perfect state as when they were first finished. The cellular variety is used with some success as a material for millstones. It is also employed as a building stone, a flux for certain iron ores, and as an ingredient in dark green bottle glass: the fine-grained is used as a touchstone. Basalt also when torrefied and pulverized, communicates to common mortar the property of hardening under water. ^d

The origin and formation of basalt has long been and still continues a subject of animated controversy among geological philosophers. The first mineralogists considered it decidedly as of volcanic origin, from its colour, its sonorousness, and the regular arrangement of its prisms. Bergman introduced the theory of its aqueous formation, from observing that the strata which are in immediate contact with basalt, generally exhibit appearances incompatible with the known action of fire upon them. Since the time of this great chemist, the two theories have nearly equally divided the mineralogical world, both with regard to numbers and abilities. The Swedes, the Germans, and the disciples of Werner in Britain, have taken up the aqueous theory: they have shewn basalt resting upon and alternating with strata of acknowledged aqueous origin, they have discovered shells and vegetable remains imbedded in its substance, they have found its cavities filled by siliceous nodules containing water, they have melted basalt in their furnaces and have found it to

produce a glass, they have shewn that the lava of Vesuvius and Etna differs in many important particulars from basalt; and they have pointed out the prismatic structure in many substances, which are not supposed even by their antagonists to have undergone the action of fire.

The French, the Italians, and Dr. Hutton and his partizans in Britain, have for the most part adopted the opinion of the igneous origin of basalt: they have shewn the prismatic structure of some undoubted Italian lavas; they have shewn beds of coal charred by the contact of dykes of basalt, and the forcible disruption, incurvation and induration of argillaceous strata when pierced through by veins of this substance. Sir James Hall has proved that basalt, after it has undergone the vitreous fusion, may be made by slow cooling to assume a perfect stony appearance, and Mr. Watt's admirable experiments ^e demonstrate that basalt may by the medium of fire acquire those peculiarities of structure which are not easily explained on the aqueous theory, and that although deprived of its magnetic power when in the vitreous state, it recovers it again as it resumes by slow cooling its earthy prismatic texture.

For further remarks on the fusion of basalt see VITRIFICATION.

BASALTINE. See HORNBLÉNDE.

BASALTINE, octahedral. See AUGIT.

BASANITE. See KIESELSCHIEFER.

BATH in *Chemical apparatus*. (See the Appendix.)

BAY SALT is a very pure salt, prepared from sea water by spontaneous evaporation. See MURIAT of Soda.

BEILSTEIN. See NEPHRIT.

BELL-METAL. See COPPER, *Alloys of*.

BENZOIN Gum, or BENJAMIN. BENZOIC Acid. The gum resin that bears the name of Benzoin or Benjamin, is brought chiefly from the East Indies, in large brittle masses, of unequal degree of purity and varying in colour from yellow to white. It has scarcely any taste when chewed, but if previously dissolved it is moderately pungent and aromatic. Its smell is extremely grateful when rubbed or gently warmed, this encreases as the heat is raised, and when the resin melts, a very white and most fragrant vapour rises, which is so pungent as to excite violent coughing, and soon condenses on the surrounding bodies in beautiful shining saline needles. This salt is the *benzoic acid*.

Gum benzoin is very soluble in alcohol, but

^a Nicholson's Journ. 4to. vol. v. p. 322.

^b Ann. de Chim. vol.

^c Philos. Transf. 1804, p. 279.

most of it separates again on the addition of water. Boiling water has no other effect on benzoin than to melt it, and to dissolve out a small portion of its acid, but the resin itself remains insoluble. By distilling this resin without addition it resolves itself into the acid, and into a fine fragrant oil which rise nearly together, and, by a greater heat, an empyreumatic oil is given off, and a spongy coal remains behind.

Benzoin is the most important of the class of *balsams* in modern chemistry, which are understood to be, resins naturally united with that volatile crystallizable acid which has just been mentioned, and which is the same in all the natural balsams.

The white resinous precipitate, which is formed by adding water to the tincture of benzoin, has been called *lac virginale*. When gently dried it is a yellowish white powder, sometimes used as a cosmetic.

The *benzoic acid* may be prepared either by sublimation or by digestion. The former method is the most ancient.

Put any quantity of benzoin, pure or impure, into an earthen vessel (a common pipkin will answer the purpose) and paste to the top of it a large cone of white paper, or join to it another pipkin inverted and fitting pretty close, or in short any kind of contrivance to receive and condense the vapour. Set the apparatus on a very gentle charcoal fire, or over a lamp, so that only the lower vessel may be warmed, and heat it no more than is sufficient to melt the resin. The white suffocating fragrant vapour rises almost immediately in extremely dense fumes, and condenses in the upper receptacle in uncommonly brilliant clusters of small needle-formed crystals. Continue the process till nearly all is expelled at that temperature. The benzoin however still retains some acid, which may be expelled by encreasing the heat, but then at the same time some of the yellow fragrant oil of benzoin arises, which impairs the whiteness and purity of the acid. From nine to twelve drachms of the acid may be obtained in this way from sixteen ounces of benzoin.

The other method of preparing this acid is that which was discovered by the celebrated Scheele. It consists in first heating the benzoin with lime water, whereby the acid unites with the lime, forming a benzoat of lime, soluble in water, and then separating the benzoic acid by the muriatic, which unites with the lime by superior affinity. Some management however is requisite to prevent the benzoin from

running together when melted by the heat of the boiling water, and swimming at the top in a mass impenetrable by the liquor. Scheele advises the following: pour 12 ounces of water upon 4 ounces of well burnt lime, and when slacked add 6 pounds more of water. Then put a pound of finely powdered benzoin into a tin pan, with 6 ounces of the above lime-water, mix them well together, after which add the rest of the lime-water. The benzoin will thus be prevented from running together. Boil for half an hour with constant stirring, and strain the liquor through a cloth. Repeat the boiling with fresh lime-water, and strain as before, pressing the residue to extract all the liquor. This is now a very weak solution of benzoat of lime, the benzoic acid having united with the lime contained in the lime-water. Boil down this liquor (which is a light yellow) to two pounds, and strain. When cold add muriatic acid, as long as any white precipitate falls down, and till the solution tastes sensibly sour. After standing some hours, collect the precipitate and slightly rinse it with cold water. It is now pure benzoic acid. The reason of its precipitation is its very sparing solubility in cold water when no longer united with lime. Boiling water dissolves $\frac{1}{20}$ of its weight of benzoic acid, but cold water only $\frac{1}{400}$, and hence almost all the contents of a hot saturated solution are deposited on cooling. More benzoic acid is procured by the intermede of lime than by simple sublimation. Scheele obtained in this way from 12 to 14 drams from 16 ounces.

Cream of lime, or slacked lime suspended in water to the thickness of cream, will answer as well as clear lime-water, and a less bulk of liquid will thus suffice, which will shorten the evaporation. The acid procured in this way is in the form of a granular powder. It may be made into spicular crystals by redissolving in boiling water and cooling. Almost any acid will separate the acid from the benzoat of lime, but the muriatic is the most convenient. The sulphuric is not so proper, as the sulphat of lime when produced will partly fall to the bottom and mix with the benzoic acid.

A small quantity of the acid may be extracted from gum benzoin, merely by boiling in water, which crystallizes as the water cools, but with the inconvenience above mentioned, of the resin melting together in a mass, which swims at top, and prevents the water from penetrating it.

Crystallized benzoic acid, particularly that obtained by sublimation, is remarkably light,

feathery and elastic. When pure it is quite white, for the yellowness is owing to the admixture of oil. But as it retains its fragrant smell through successive crystallizations and solutions, it is probable that a portion of oil remains in very close union with it, and hence perhaps the extreme weakness of its affinity with earthy and alkaline bases.

In solution with water the taste of the acid is sharp, sourish and pungent, and it reddens litmus. Heated without addition a part sublimes unaltered, but the rest is decomposed into the usual products of vegetable matter. Thrown on hot coals it burns readily with a most pungent smoke.

Benzoic acid is also contained in styrax and balsam of Tolu, giving them the characters of true balsams according to the modern system; and it is met with more sparingly in several of the fragrant barks, resins and other vegetable matters. It generally appears in its proper character when these substances are gently heated, or it may be extracted with lime in the way above mentioned.

BENZOATS. These are too little known to require separate description. The benzoic acid unites with all the alkalies and most of the earths, forming generally soluble salts, from all of which the acid may be separated by the muriatic, as above described, from the benzoat of lime. Many of the metallic oxyds are soluble in this acid, but not the metals themselves. The *benzoat of lime* has been discovered by Fourcroy in the urine of the horse, and some other herbivorous quadrupeds. It appears to be the cause of the sub-aromatic smell sometimes perceived when these animals stale.

The affinities of this acid appear to be in the following order: lime, barytes, magnesia, potash, soda, ammonia, alumine and metallic oxyds.

BERGHOLZ. See ASBEST.

BERGKORK. See ASBEST.

BERGKRISTAL. See QUARTZ.

BERGMILCH. Agaric mineral.

The colour of this mineral is yellowish-white, approaching to snow-white and greyish-white: it is composed of slightly-cohering very fine particles; it is dull, opaque, has a meagre feel, soils the fingers when handled, and is so light as nearly to float on water.

It effervesces strongly, and is entirely dissolved in acids. It has not been formally analysed, but appears to be a pure or nearly pure carbonate of lime.

It is found in fissures and holes of secondary

limestone in Switzerland, and at Sunderland in the county of Durham. It is not made any use of.

BERGSEIFE.^a Mountain soap.

This mineral was first described by Werner. Its colour is brownish black, passing into smoky-grey: it is found in mass and disseminated: internally it is dull: its fracture is fine-earthly, passing into flat conchoidal. It is opaque, does not stain the fingers, gives a shining resinous streak, is very soft, adheres powerfully to the tongue, and is light.

It has not been analysed; and bears a considerable resemblance to indurated lithomarge.

It is found in rocks belonging to the secondary trap-formation, and is very rare: the only places where it has yet been discovered are, Otkuschi in Poland, in Bohemia, where it is used for washing linen, and in the isle of Skye in Scotland.^b

BERNSTEIN. See AMBER.

BERYL. See EMERALD.

BEZOARD Mineral is a perfect oxyd of ANTIMONY, made by digesting in nitric acid the precipitate from butter of antimony by water.

BILDSTEIN.^c Agalmatolite of Klaproth. Talc glaphique, Haüy.

There are two varieties of this mineral, the semitransparent and the opaque.

Var. 1. Semitransparent. Its colour is olive and asparagus green, passing into greenish grey: internally it is shining and has a greasy lustre: its parallel fracture is obscurely flaty, its cross fracture is small splintery, passing to compact uneven: it is translucent passing to semitransparent, is soft, and has a greasy feel. Sp. gr. 2.81.

It has been analysed by Klaproth, and appears to contain

54.	flex,
36.	alumine,
0.75	oxyd of iron,
5.5	water.

96.25
3.75 loss

100.00

Var. 2. Opaque. This differs from the preceding in the following particulars. Its colour is reddish-white passing into flesh-red and variegated with different coloured veins: it possesses little or no lustre, and has a compact fracture:

^c Haüy, Emmerling, Klaproth Analyt. Ess. v. i. p. 465.

^a Widemann, p. 436.

^b Jameson's Mineralog. p. 396.

it is opake or at most translucent on the edges.
Sp. gr. 2.78.

It is composed, according to Klaproth, of

.62	silica,
.24	alumina,
1.	lime,
0.5	oxyd of iron,
10.	water.

97.5
2.5 loss

100.0

The bildstein comes from China, and is the substance of which the little Chinese ornaments and figures for chimney-pieces are made. It has usually been considered as a variety of steatite; but from the total absence of magnesia in its composition, and its external characters, appears to be nearly related to lithomarge.

BILE. *Galle*, Germ.

This most important animal fluid is secreted in all animals by the liver, and is generally one of the most abundant of all the animal secretions. Some are also furnished with a reservoir or bag, subsidiary to the liver, and called the gall-bladder. The use of this organ is foreign to the present subject, but its existence gives rise to some distinction between the bile of the liver and that of the gall-bladder, the *hepatic* or *cystic* bile.

All the experiments undertaken in a large way have been upon the *cystic* bile, or that of the gall-bladder, on account of the ease with which this is procured after death, whereas that of the liver can only be obtained with difficulty and in very small quantity. It does not appear however that any material difference exists between the two, except that the *cystic* is somewhat thicker than the *hepatic*; nor have any satisfactory experiments been made to determine whether the kind of food taken in, or the species of animal, causes any alteration in the quality of bile. That of the ox, commonly called *ox-gall*, has usually been selected, though the description of its chemical properties will without doubt apply with very little variation to every species of bile.

Bile is a yellowish-green fluid, viscous and tenacious like white of egg diluted, and of a density greater than that of water. The specific gravity is given so differently by various writers that it certainly varies considerably, according to the age, food, health, &c. of the animal.

It may be said to be from 1.02 to 1.04. The smell of recent bile is peculiar and often sub-aromatic, but this changes to a very peculiar foetor when putrid. To the taste it is intensely bitter (so much as to be proverbial) and sub-saline: it froths violently when beaten up, and mixes with water, though slowly, in any proportion. It shews strong marks of a predominant alkali, by changing blue vegetable colours to green, and, as will presently be seen, it actually contains soda in excess, but not carbonated.

Bile gently heated does not coagulate, but loses the greater part of its water, and by keeping the temperature within the boiling point of water and long evaporation, it loses nearly seven-ninths of its weight^a of an insipid liquid, differing in nothing from pure water, except by having a faint unpleasant smell.

The residue when cold becomes dry, brittle, of a dark brown, intensely bitter, but at the same time somewhat sweetish, and very inflammable. When exposed to air it deliquesces and resolves itself into a thick pitchy mass. It also readily softens by the heat of the hand, and melts over the fire. It may be now preserved a very long time without putrefying, but bile itself begins to be very fetid and somewhat putrid in a few days in summer, though later than most of the animal juices. In this state a smell of musk is also very perceptible.

The thick *extract* or *inspissated bile* when heated in a retort without addition, gives out first a watery liquid containing some sulphuretted hydrogen,^b whilst the bile in the retort puffs up to a prodigious bulk. A red liquor follows, which contains an empyreumatic oil, at first clear and not ungrateful, but afterwards foul and extremely fetid. Some carbonat of ammonia rises, but in remarkably less quantity than is yielded from most animal substances of similar consistence.^c Carbonic acid, carburetted hydrogen, and other gasses follow in great abundance. A black spongy coal is left, which is deliquescent in the air, and after some days shews a saline efflorescence of carbonat of soda. This alkali is also left in the ashes of the coal when thoroughly burnt in the open air. The analysis by fire alone does not throw much light on the composition, any further than to shew the presence of uncombined soda, which remains in the ashes after every thing else has been expelled. It is by other means that the nature of bile is more fully detected.

The extract of bile inspissated by gentle heat,

^a Van Bochante. Jour. de Phyl. tom. 15.

^b Fourcroy, Syst. de Conn. Chim.

^c Van Bochante.

though it has some of the appearance of a resin and burns like one, is still readily again soluble in water, and appears thereby to return nearly to the state of unprepared bile.

Alcohol and acids are the most valuable reagents for discovering the true nature of bile.

If dilute muriatic acid (and any other will answer the purpose) is added to bile, a greenish coagulum is immediately formed, which when collected is very tenacious, and intensely bitter. The clear liquor still remains bitter as well as sour, but if the acid and the bile are boiled together^d the separation is more perfect, the liquor is now scarcely bitter, and has little other taste besides that of the acid added, whilst the whole of the sapid and colouring matter of bile has gone into the precipitate, which is now intensely bitter, of a dark green and tenacious, and may be dried into a brittle resin-like mass. This however is different from simply inspissated bile in being deprived of the soda which is natural to this fluid, and this alkali is now found, on evaporating the clear liquid, united to the muriatic acid, and crystallizes in small cubes when the evaporation is carried nearly to dryness. If sulphuric acid has been used to decompose the fresh bile, the salt is sulphat of soda, if the nitric acid, nitrat of soda,^e and by this most satisfactory experiment the presence of the naked alkali is fully demonstrated. No sensible quantity of muriatic acid in any form appears to exist in bile, as it shews no precipitate with nitrated silver.

The dark green bitter coagulum separated by the acid is found to consist of at least two substances, one, an animal matter resembling albumen in most of its properties, the other a peculiar resinous matter, in which resides the colour and bitterness of bile, and which was before held in solution as a kind of soap with the soda, which afterwards quitted it to join the acid. Acids therefore act here in a double capacity, they precipitate the albumen, as they always do whenever they come in contact with it, and they also precipitate the resinous matter by detaching it from its union with the soda, which makes it soluble in natural bile. The biliary resin and soda appear to form a pretty close union with the albumen in recent bile, for when this liquid is heated to boiling, none of the albumen visibly coagulates, and the bile remains as clear as ever, which could not take place unless the albumen were prevented from coagulating by some intimate union with a substance uncoagulable by mere heat. Even when

white of eggs is previously mixed with the fresh bile and heated to boiling, no coagulation takes place, so that the biliary resinous soap is able to prevent this separation in a much greater quantity of albumen than is natural to the bile.

The precipitate formed by acids has been mentioned to consist of albumen and a substance which may be called *biliary resin*. These are entirely separable by alcohol, which only dissolves the resin, forming a dark brown bitter tincture, whilst the albumen remains behind. This tincture, though it resembles the tincture of simply inspissated bile in colour, taste and inflammability, differs from it in some material points. The latter (as it retains its soda and albumen) is uniformly miscible with water, and is in appearance much more like a soapy tincture; the former closely resembles the tinctures of the vegetable resins, and on the addition of water becomes instantly turbid and parts with nearly all that it had dissolved, which subsides as a dark pulverulent mass not soluble in water.

Alcohol added to bile gives an immediate coagulum, which is nearly white, and when washed in water, in which it is now insoluble, it retains scarcely any bitterness, burns on coals like horn, and is nearly pure albumen. The liquor from which it has separated is green and bitter, and contains both the biliary resin and the soda. Evaporated to dryness it leaves a fine resinous soap, which on account of the soda remains equally again soluble in water as in spirit. If the bile is first inspissated, and the alcohol then applied, it dissolves out of the thick extract only the resin and soda, leaving the albumen. This latter solution is itself decomposed by acids, which, uniting with the soda, precipitate the biliary resin pure.

The alkalies render bile more fluid, but produce no remarkable change. When concentrated they disengage a little ammonia. Barytic, strontian, and lime-water added in large quantity unite with the resin, and form an insoluble soapy precipitate.

The metallic salts decompose, and are decomposed by bile, forming precipitates consisting chiefly of albumen, and of the metallic oxyd united with the biliary resin.

Some phosphoric salts are also to be found in bile, though in small quantity.

The resin of the bile, though resembling the vegetable resins in solubility in alcohol, insolubility in water, brittleness, inflammability, &c. has some properties which shew it to be of a peculiar nature.

^d Saunders on the Liver.

^e Cadet.

Fourcroy has further examined this curious substance. On passing the oxymuriatic acid gas through fresh bile diluted with a little water, the first effect is to coagulate the albumen, which is deposited in white flocculi. At the same time both the smell and colour of the bile entirely disappear, but the intense bitterness remains. On continuing the process, the greater part of the resin separates in the form of a white, unctuous, concrete mass. Any other acid produces the same precipitate, if added after the bile has absorbed so much of the oxymuriatic acid as to lose its colour. This white concrete substance differs considerably from the resinous precipitate formed by the simple muriatic or other acid, and rather resembles *adipocire*, for it is soluble easily in hot water (which the resin is not) and also in alcohol, which liquor during the solution passes nearly to the state of ether. This alcoholic solution is also miscible with water (in which it differs from the resin), and is again separable thence by muriatic acid. It more resembles the foliated substance contained in *Biliary Calculi*. These curious experiments deserve repetition.

It is uncertain whether that which gives colour and odour to the bile is a separate principle, or whether it resides in the resin.

Some chemists have imagined a saccharine matter in bile to be indicated by the sweetish taste of the inspissated extract, and the tendency to vinous fermentation which it assumes by keeping, but its existence is by no means clear.

Bile putrifies with difficulty, for though it soon acquires a very nauseous smell by keeping, the putrefaction advances very slowly and imperfectly. If it is boiled a few minutes in this state it becomes very green, and is long preserved from further alteration. When thickened by evaporation to a syrupy consistence, it will remain fresh for many months, during which it assumes somewhat of a vinous smell. In any case the bitterness remains apparently unaltered.

Bile has been occasionally employed with advantage in medicine, when dissolved in alcohol or inspissated. But its chief use out of the body is a detergent to scour wool and cloth, remove grease, spots, &c. Ox-gall is chiefly turned to this purpose. It here seems to act as a kind of soap, but with superior powers as a detergent, than the mere quantity of alkali in it would indicate.

The same property of mixing with and dissolving oily matters renders bile useful to painters in various ways. Ivory when rubbed with

ox-gall loses its greasy gloss, and is thereby much fitter to receive colours, and the gall itself is used to mix greens, bistre, and some colours where the greenish yellow of the gall is not perceived. As no animal has been found destitute of bile, it appears a most essential fluid to the animal economy.

BILIARY CALCULI. Hard concrete roundish substances are often found in the gall bladder, or more particularly in the ducts from the liver and the gall-bladder to the intestine, or sometimes passed on into the bowel itself, and which during life are often the cause of a most painful disease. These concretions have attracted the notice of chemists.

Biliary calculi (or *gall-stones* as they are also termed) vary much in external appearance as well as chemical properties, though there is upon the whole more similarity between these than between urinary calculi. The colour is generally green or yellowish brown, sometimes white; in shape they are often oblong, sometimes tuberculated. When cut through they most frequently consist of a radiated semi-crystalline mass, internally often resembling spermaceti, coated with several concentric laminæ.^a The radiated part is mostly white and then tasteless, the laminated is sometimes bitter.

Gall-stones are distinguished for their lightness and inflammability, few of them being so heavy as to sink in water, and when put to a lighted candle they generally melt like wax and kindle with a bright flame, attended with very little ammoniacal smell. From the infinite minute varieties in gall-stones no natural arrangement is indicated, but the most important indications for analysis are the proportion of the crystallized radiated part, and the general lightness and inflammability.

Gall-stones are usually largely soluble in oil of turpentine, and in all the essential oils by heat. Alcohol when cold has but little action, but when boiled it dissolves almost all the inflammable part, leaving an earthy residue behind. On cooling, this solution deposits very copious spicular crystals, strongly resembling those of spermaceti treated in the same way, and this singular substance forms by far the most curious part of the composition of these concretions. Pouletier and Fourcroy^b have both attended minutely to this substance. The former discovered similar crystalline concretions in a piece of liver long exposed to the air.

When the hot alcoholic solution of this concrete is dropped into a large quantity of water,

^a Baillie Morbid Anat.

^b An. Chim. tom. 3.

a white flocculent precipitate is formed, which when dried is found to be of a resinous nature. The supernatant liquor, by saturation with muriatic acid and evaporation, gives muriat of soda,^c by which it is evident that this alkali remains in union with the biliary resin after it has undergone the change (as yet not quite understood) into biliary calculus.

Ether and oil of turpentine dissolve the spermaceti-like concrete, and deposit the greater part in crystals on cooling. Hot nitric acid acts upon it readily with disengagement of nitrous gas. When cool, a white oil concretes on the surface of the acid, now no longer of a crystalline texture, and altered in its properties, being brittle and friable like a resin, and when redissolved in alcohol it does not again crystallize on cooling.^d It is still insoluble in water. Ether dissolves this altered concrete as it did in its natural state, but water again separates it in the form of *drops of oil*.

These singular anomalies shew that the radiated crystalline part of biliary calculi is considerably different from spermaceti or adipocire, and to the physiologist the subject is worth pursuing.

BIMSTEIN. See PUMICE.

BIRDLIME is a very singular kind of tenacious cement prepared from the bark of some trees, particularly the holly, and also from the mistletoe. The holly bark is first boiled for ten or twelve hours, which separates the green outer coat from the inner, it is then covered up for a fortnight in a moist place, and afterwards pounded into an uniform paste, washed in water, fermented for four or five days, and laid up for use. When used, it is incorporated with a third of its weight of nut oil. Many other vegetables yield by maceration a similar stringy tenacious juice, insoluble in water and miscible with oils.

BISMUTH. *Wismuth*, Germ.

Bismuth is a metal of a very dilute yellowish and reddish white colour; it is brittle, has a lamellar texture, and is divisible, parallel to the sides of a regular octahedron, is more fusible than lead, and is readily soluble in nitrous acid, from which it is almost entirely precipitable in the form of a white powder, by the addition of water.

The ores of bismuth are comparatively of rare occurrence, and are arranged by mineralogists under the three following species.^e

I. Native Bismuth. *Gediegen Wismuth*. *Bismuth natif*. Haüy and Brochant.

The colour of this substance is silvery-white, verging more or less upon red; it is often iridescent on the surface. It occurs disseminated, or superficial, feather-shaped reticular or cellular, rarely in mass and very rarely crystallized. Its forms are very small quadrilateral tables and cubes. It possesses both externally and internally a brilliant metallic lustre. Its fracture is lamellar or broad radiated, and generally exhibits granular distinct concretions. It is soft, and in some degree ductile. Sp. gr. 9.57.^f It fuses very easily, and is entirely dissipated before the blowpipe in a yellowish white smoke. It has not been regularly analysed, but often contains besides bismuth a very small portion of arsenic and cobalt, hence when melted it exhales a slight alliaceous odour.

It is found in the veins of primitive mountains in a gangue of quartz, calcareous spar or heavy spar, indurated clay or jasper, accompanied by cobalt, kupfernickel, and occasionally by native silver, blende and galena. It is met with in Bohemia, Saxony, Transilvania, Sweden and Brittany.

II. Sulphuretted Bismuth. *Wismuth glanz*. *Galene de Bismuth*. *Bismuth sulfuré*, Haüy.

Its colour is between tin-white and lead-grey, the surface being often yellow or iridescent. It occurs in mass or disseminated, or more rarely in small lamellæ or acicular crystals implanted in each other. Its fracture is generally radiated, sometimes lamellar. Its lustre is brilliant metallic. It generally stains the fingers, and gives an obscurely metallic streak. Sp. gr. 6.13.

It melts easily and gives out a sulphureous odour and blue flame, but is with difficulty freed from the whole of the sulphur. According to the analysis of Sage and La Peyrouse it contains about 60 per cent. of bismuth, 36 of sulphur and a little iron. It is distinguishable from galena by its superior fusibility, and by not breaking into cubical fragments, and from sulphuret of antimony by being somewhat less fusible, and by not being entirely evaporated before the blowpipe.

This mineral is extremely rare, it has been found accompanying native bismuth in Bohemia, Saxony and Sweden.

A variety of this ore with a more than usual silvery appearance is described by Born as a molybdic silver, *wasserbley silber*; it has however been lately analysed by Klaproth, and contains 75 per cent of bismuth and 5 of sulphur.

^c Saunders.

^d Bostock, Phil. Journ. vol. 6. p. 136.

^e Kirwan, Brochant, Haüy, Emmerling, Widenmann.

^f Kirwan.

III. Bismuth ochre. *Wismuth okker*. *Bismuth oxyde*, Haüy.

Its colour is yellowish grey passing into ash-grey, greenish grey or straw-yellow. It occurs very rarely in mass, but more commonly disseminated or investing the surface of other minerals. Internally it possesses a common shining lustre. Its fracture is fine-grained uneven or earthy. It is tender, often friable: and is heavy, but its exact specific gravity has not yet been ascertained.

It is soluble in nitrous acid *without* effervescence according to Kirwan, but *with* effervescence according to Brochant, and before the blowpipe on charcoal is easily reduced to a metallic globule. It appears to be a pure oxyd of bismuth, occasionally combined with carbonic acid.

Bismuth ochre is very rare, and is found principally at Schneeberg in Saxony, accompanying native bismuth.

The reduction of the ores of bismuth is very easy on account of its ready fusibility and the slightness of its affinity with sulphur. The native and oxidated bismuth are worked in the great way simply by heating the ore in contact with burning fuel. For this purpose some dig a shallow hole in the ground, fill it loosely with wood and bushes, and when the fire is kindled throw upon it the ore broken in pieces. Others fill the hollow of the stump of a pine tree alternately with wood and with the ore, and set it on fire. In either case the bismuth melts out from its matrix, and is found in a mass at the bottom. For the nicer purpose of assay more exactness is requisite.

The native and the oxidated bismuth are thus reduced: mix them with their weight of black flux, put into a crucible, cover with salt to about a fingers' breadth, and melt for five minutes with a pretty brisk fire. When cold, the bismuth is found in a clean button beneath the scoria. Gellert^s uses one part of borax and the same of powdered glass to two of the ore, and fuses in a crucible lined with charcoal, which is perhaps still more exact; but where the oxyd is used it should also be mixed with a little oil, rosin or charcoal.

The sulphuret should first be roasted for a moderate time to expel most of the sulphur, which is not difficult to drive off, and then mixed with black flux and treated as the former. In this manner Sage obtained 60 of metal from 100 of the roasted oxyd.ⁿ No great intensity of heat is required in these reductions. The

metal thus obtained is not however pure, as it retains any lead, silver and other metals with which it may be naturally combined. The quantity of silver may afterwards be known by working off a determinate weight of the bismuth on a cupel in the manner of lead, as described in the article ASSAY. When the process is finished, the oxyd of bismuth will be entirely absorbed by the cupel, and with it all the base metals, and the silver alone will remain in the metallic state. To determine the exact proportions of the other metals, recourse must be had to the humid way of assaying. No previous roasting is here requisite. The nitrous acid diluted with no more than a third of water is the best menstruum. The native or simply oxidated metal dissolves readily in this acid in the cold or only with a gentle heat; the sulphuret requires boiling, whereby the sulphur is precipitated and the bismuth dissolved. It is a striking property of the nitrat of bismuth to let fall almost the whole of the metal in the state of a fine white oxyd when drenched with water. Hence by far the greater part may be separated from lead, iron, copper, silver and cobalt, with which it is more commonly alloyed, by this simple method; the nitrats of these other metals not being decomposed by large dilution. To separate the bismuth totally, let the clear liquor remaining over the precipitated oxyd be evaporated to a very small bulk, so as just to hold in solution the nitrated metals, or if part of the nitrated lead crystallizes (which it will do the soonest of the above nitrats) dilute again with just water enough to redissolve it. Then add muriatic acid by dropsⁱ as long as any white cloud appears. This second precipitate consists of the remaining portion of oxyd of bismuth mixed with the muriat of silver, if this metal was contained in the solution. Add a few drops of strong nitric acid to this, which will dissolve the bismuth and leave the silver, and again drench this second portion of nitrated bismuth with water, which will now separate the whole. Hence the obstacle to the total precipitation of the bismuth in the first instance appears to be the great dilution, for the remaining portion is obtained by again making a concentrated solution. It may be worth observing that as the muriat of silver very speedily turns of a slate colour when exposed to light, this trial should at first be made with the precipitate by muriatic acid, and if the pure full white is not altered, it is a proof that no silver is contained, and the white precipitate may then be set down as oxyd

^s Chimie Docimast.

ⁿ Mem de l'Acad. 1782.

ⁱ Klaproth.

of bismuth and added to the first quantity. According to Klaproth 100 grains of metallic bismuth make 123 grains of the white oxyd, whence this oxyd is composed of 81.3 per cent. of bismuth and 18.7 of oxygen. The bismuth and silver being thus disposed of, the nitrated solution now contains chiefly lead, with perhaps some iron, copper and cobalt, which are obtained separate in the way described under these respective metals.

BISMUTH when pure is a white metal with a little tint of red, so brittle as to be readily reducible to powder, very brilliant in its fracture, and with a disposition to the octahedral form. Its specific gravity is 9.822. It does not readily tarnish, except exposed to any sulphureous vapours, but when long exposed to air assumes a pale violet colour. It is extremely fusible, melting at about 460°, that is, long before it is red hot. When heated very intensely in close vessels it sublimes unaltered and crystallized in plates.

Bismuth is of all the metals the most easy to crystallize artificially, and this experiment is highly beautiful. A quantity of it (the more the better) melted in a crucible, slowly cooled till the surface and sides begin to solidify, and then inverted so as to pour out the middle, which is yet fluid, will seldom fail to exhibit in the hollow left by the fluid metal, very fine cubic crystals of considerable size. Or better in the following way: bore a large hole through the bottom of a crucible and plug it up with a piece of iron, fill this crucible with bismuth, inclose it in another with sand interposed, and heat the whole red hot, covering the inner crucible. Remove both together from the fire, and let the metal cool gradually till it is crufted over at top, then lift the inner crucible out of the sand, draw out the iron plug (which will require pretty strong pincers) and allow the still fluid metal to flow through the hole. If well managed, and if some pounds of bismuth be used, remarkably beautiful crystals will thus be produced.

Bismuth also crystallizes in very perfect cubes from its solution in MERCURY. A singularly fluid amalgam is produced by mixing equal parts of amalgam of bismuth with amalgam of lead (each composed of equal parts of mercury and the other metal), and from this, which is nearly as fluid as running mercury, the bismuth crystallizes by repose.

When bismuth is kept at a low red heat with full access of air, the surface is gradually con-

verted into a dull grey oxyd. By skimming it off and exposing fresh surfaces, the whole is thus changed. A hundred parts of the metal were repeatedly found by Geoffroy* to acquire 10 parts in weight by this process, so that 100 parts of this oxyd would consist of 90.9 of metal and 9.1 of oxygen. With a moderately strong fire this melts into a greenish yellow glass. If bismuth is very strongly heated, as on the blowpipe, especially with oxygen gas, or thrown into a crucible white-hot, it takes fire and burns with a bluish flame and a dense smoke, which quickly settles on the surrounding cooler bodies in the form of a yellowish powdery oxyd. This deflagration is remarkable when bismuth is used with silver in assaying, instead of lead, and the heat is raised too suddenly: it then suddenly spirts out on every side globules, which burn with a very brilliant flame within the muffle. Bismuth also burns very well with a whitish blue flame when thrown, finely powdered, into a flask of oxymuriatic acid gas. The oxyd of bismuth by heat may be prepared with a proper subliming vessel, allowing a sufficient current of air upon the strongly heated metal. This sublimed oxyd is no further volatilizable by any heat, but readily melts (like the grey oxyd) into a yellowish green glass. When melting it acts a little on the crucible, but not nearly with the same energy as the vitreous oxyd of lead. It does not give a glass of much body of colour when fused with vitrescent mixtures. It does not appear quite certain from any accurate experiments whether there exists more than one state of simple oxidation of bismuth by heat, but as Geoffroy estimates an increase of 10 in 100 of metal by calcination, it is probable that the oxyd when fused does not contain more than this proportion, and would therefore be composed of 90.9 of metal and 9.1 of oxygen; whilst the oxyd by nitrous acid, according to Klaproth, consists of 81.3 of bismuth and 18.7 of oxygen. The sublimed oxyd or *flowers* perhaps approaches more to the latter state of oxygenation.

The sulphuric acid has no action on bismuth in the cold, in whatever state of concentration, but at a boiling heat the strong acid partly dissolves, and partly oxidates the metal, giving out sulphureous acid gas and some sulphur. If the acid be distilled off nearly to dryness, on cooling there are found lying on the oxyd a number of small feathery crystals of sulphat of bismuth. A small addition of hot water dissolves out these crystals, which are again mostly deposited on

* Mem. de l'Acad. 1753.

cooling. A large quantity of cold water decomposes the sulphat as well as the nitrat, and gives a copious white precipitate.

The action of the nitric acid on bismuth has been mentioned in the analysis. It is extremely vehement when the acid is at all concentrated, and attended with a copious emission of red nitrous vapour. The strong acid only oxidates the bismuth, a small dilution is requisite to hold much of it in solution. The nitrat crystallizes by slow evaporation.

The oxyd precipitated from the nitrat by water has long been used as a cosmetic on account of its exquisite whiteness, but much care is required to give the preparation its most saleable excellence. It is the basis of the *Fard* or *blanc de Fard*. The chief precautions requisite appear to be the purity of the water, and great perseverance in washing and edulcorating the precipitate. Artists distinguish two sorts of bismuth-white; the *blanc de fard*, which is a fine powder of a pure dead white; and the *blanc de perle*, which has a very beautiful glistening appearance very like the lustre of pearls. The exact way of preparing this last is kept a secret, but it is probably made by using the muriatic acid much diluted as the precipitant instead of pure water, for a brilliant pearly white is given by this method. Some employ the nitro-muriatic acid, carefully freed from all admixture of the sulphuric, as the solvent for the bismuth.¹

Muriatic acid acts on bismuth only when hot and highly concentrated. A fetid hydrogenous gas is given out during the solution. The oxyd is more soluble. Muriat of bismuth crystallizes in long needles: it is decomposed by much water, as well as the nitrat. This salt when evaporated to dryness and distilled *per se*, gives a thick sublimed *butter*, which is easily fusible at a gentle heat, and almost totally decomposable by water.

If the oxyd of bismuth is rubbed with muriated ammonia, a smell of volatile alkali is immediately perceivable, and by heat all the ammonia is expelled, and a muriat of bismuth remains which readily sublimes by heat.

The oxygenized muriatic acid dissolves bismuth or its oxyd very readily. In the gas the metal burns with a blue flame, as already mentioned. The salt remaining after the action of this acid is the *butter*, by some termed the *oxymuriat of bismuth*, but the precise action of this acid, and the difference between the crystallized muriat and the butter are not exactly known. The butter is also produced by distilling

equal parts of bismuth and corrosive mercurial muriat.

The phosphoric acid acts but little on bismuth, but dissolves its oxyd without difficulty into a white saline mass very little soluble in water. By heat this melts into an opaque white glass.

Acetous acid dissolves the oxyd though with difficulty and only in small quantity. This solution is not precipitated by water.

Many of the other acids dissolve the oxyd of bismuth, but with no appearance worth remarking.

In general it may be observed that the solutions of this metal do not give a *saline* precipitate with the sulphuric and some other acids, as the solutions of lead and some of the other white metals do, and when any precipitate is formed it is merely the oxyd. Hence these acids decompose the solution, probably merely on account of the water with which they are mixed. Thus *dilute* muriatic and *dilute* sulphuric acid precipitate only a white oxyd of bismuth from the nitrous solution, and not a muriated or sulphated oxyd, as would happen with the nitrats of lead, silver, &c. and the *concentrated* acids give no precipitated oxyd at all. This circumstance is of great use in analysis, in separating bismuth from other metals. All the salts of bismuth when in solution have an excess of acid.

The carbonated alkalies precipitate from all the acid solutions of bismuth a white carbonated oxyd of bismuth.

Neither the fixed nor the volatile alkalies act upon bismuth, but in some degree upon the white oxyd. This latter boiled with caustic potash or soda, is dissolved, though not in a large proportion. Ammonia acts with more ease and without heat. If this alkali is dropped into nitrated bismuth, it first precipitates an oxyd which it afterwards redissolves.

Bismuth unites easily with sulphur by fusion. The sulphuret thence resulting is a black brittle mass, requiring more heat to melt it than the reguline bismuth. Three parts of bismuth in powder, mixed with one of flowers of sulphur and melted in a covered crucible, give a compound much resembling the native sulphuret, and if poured out when nearly cooled, six-sided prismatic crystals are found on the sides of the crucible, projecting into the cavity left by the loss of the fluid part. The sulphur is easily separated by nitric acid. The sulphuretted alkalies also combine readily with bismuth. If any of these is poured into an acid solution of

¹ Gren.

bismuth, a mutual decomposition takes place, and a black hydrofulphuretted sulphuret of bismuth is precipitated. Sulphuretted hydrogen added, either in gas or dissolved in water, to the solutions of bismuth, instantly blackens them and precipitates a hydrofulphuret of bismuth. A *sympathetic Ink* is made by this method, which is colourless till exposed to sulphureous vapours, which immediately blacken the characters written with the bismuthic solution. The white oxyd also quickly becomes of a dirty brown when exposed to sulphureous vapours even in a very small degree, and hence its use as a cosmetic is liable to some inconveniencies.

Phosphorus can scarcely be made to unite with bismuth, and in so small a quantity as not sensibly to alter the natural appearance.

The fat oils when melted dissolve the oxyd of bismuth with great ease and form a thick plastery mass, as with the oxyd of lead.

Bismuth unites more or less readily with most other metals, and some of these alloys are remarkable for their extreme fusibility. Sir Isaac Newton's fusible metal is composed of 8 parts of bismuth, 5 of lead and 3 of tin, and when this is thrown into water and heat applied it actually melts a little before the water has reached the boiling point. No other alloy (except the amalgams, one constituent of which is naturally fluid) possesses this degree of fusibility. Many experiments have been made by D'Arcet^m on the fusibility of alloys made with different proportions of these three metals. In all, the alloy, if it did not actually melt, at least became soft and pasty at the heat of boiling water, but the proportions above given produce the most perfect fusion. It is requisite that the bismuth be about equal in weight to both the other two metals, but the proportions of these latter will admit of great variation. Bismuth and lead, or bismuth and tin alone in any proportion will not soften in boiling water. These alloys are mostly white, perfectly brittle, and tarnish with great readiness. When melted, even under water, they directly become covered with a skin of oxydated metal, and when calcined in the open air, this oxyd forms with great rapidity, and the metal beneath constantly becomes less and less fusible. This alloy is not commonly put to any use, but a similar though less fusible composition has been ingeniously applied as the material of the safety-plug to a steam-boiler for mechanical purposes.ⁿ

Bismuth is a metal very little used. It enters

into the composition of some of the soft solders, but is scarcely employed in any other way. The white oxyd is used in perfumery, and a little in medicine with apparent advantage. It furnishes two amusing sympathetic inks, one as a hydrofulphuret, already mentioned, the other by precipitation of the nitrat by means of water. If characters be written with a moderately dilute nitrat they will dry invisible, but on wetting the paper the separation of the oxyd from the nitrat will exhibit the writing in dense white marks.

The affinities of oxyd of bismuth in the moist way, in a moderate heat are—the gallic, oxalic, arsenic, tartareous, phosphoric, sulphuric, nitric, muriatic, fluoric, succinic, citric, acetic, carbonic, and prussic acids, and ammonia.

BITTER EXTRACT. See *EXTRACT Vegetable*.

BITTER PURGING SALT, or *Epsom salt*. See *SULPHAT of Magnesia*.

BITTERSALT Native. *Naturliches bitter-salz, Haarsalz. Magnesie sulfatée of Hauy.*

Its colour is greenish white, greyish white or smoky-grey. It occurs sometimes earthy, sometimes in mass, and often in capillary crystals. When earthy it is without lustre, but when crystallized it has a considerable degree of lustre between silky and vitreous. Its longitudinal fracture when in mass is curved or radiated fibrous: it is translucent, very easily broken, and has an acerb bitter taste. It consists of sulphat of magnesia, more or less mixed with iron and alumine, and probably a little sulphat of alumine.

It is found on the surface of decomposing argillaceous schistus and some kinds of limestone. The hair-salt found in the mercury mines of Idria, by Scopoli, and supposed by some to be a sulphat of zinc, by others to be a variety of plumose alum, is proved from the analysis of Klaproth^o to be sulphated magnesia with less than 1 per cent of oxyd of iron.

BITTERSPATH. *Rautenspath.^p Muricalcite of Kirwan. Chaux carbonatée magnésifère, Hauy. Spath magnésien, Brochant. Bitterspath, Miemite and Prismatic bitterspath of Klaproth.*

The colour of this mineral is greyish or greenish white, passing into asparagus green; or yellowish pearl-grey passing into light ochre and pale honey yellow and yellowish brown. It occurs disseminated or crystallized, in

1. Rhomboids either perfect or truncated at the solid angles (bitterspath.)

^m Journ de Phys. tom. 9.

ⁿ By Mr. Wood, of Burslem, Staffordshire.

^o Analyt. Ess. ii. p. 80.

^p Emmerling, Jameson, Klaproth's Analyt. Ess. i. p. 256. ii. p. 233.

2. Short somewhat oblique tetrahedral prisms, often bevelled at the edges (stänglicher bitterspath.)

3. Compressed hexahedrons (miemite.)

The crystals are small, and very small, or middle-sized. The internal lustre of bitterspath is brilliant, between vitreous and pearly: the fracture is curved or striae foliated, passing in the prismatic variety into splintery: the fragments in the first variety are rhomboidal, in the others they are indeterminately angular. It is

transparent or semitransparent, in hardness equal to fluor, brittle and easily frangible. Sp. gr. 2.48 to 2.88.

It is infusible before the blowpipe without addition, dissolves in nitrous acid slowly, and with scarcely any effervescence; when exposed to a red heat it does not decrepitate but becomes of a brownish yellow colour, opaque and soft. We possess four analyses of this substance, and all by Klaproth.

	Bitterspath from		Prismatic	Miemite.
	Tyrol.	Sweden.	bitterspath.	
Carbonat of lime - - -	52.	73.	60	53
of magnesia - - -	45.	25.	36.5	42.5
Oxyd of iron and manganese	3.	2.25	4	3
	100	100.25	100.5	98.5

Bitterspath is found in chlorite and other talcose rocks at Brienz in Switzerland and in the Tyrol, also at Taberg in Sweden, and on the banks of Loch Lomond in Scotland. The prismatic bitterspath is met with in the cobalt mines of Glucksbrunn in the territory of Gotha; and the miemite was discovered by Dr. Thomson, at Miemo in Tuscany.

BITUMEN. ^a *Bitume. Erdharze.*

The bitumens form a class of mineral inflammables distinguished by the following properties. They burn with a bright flame and much smoke, leaving behind scarce any earthy residue. When distilled *per se* they do not afford either ammonia or a concrete acid. They are not soluble either in water or alcohol. They are not ignited by nitrous acid.

The most convenient arrangement of the bitumens appears to be into the liquid, solid and elastic.

Sp. I. Liquid bitumen, or mineral oil.

Var. 1. Naphtha. *Naphte. Bergnaphtha.*

Naphtha is either colourless or of a dilute yellowish wine colour: it is perfectly fluid and transparent; has an oily lustre and is unctuous to the touch. It has a penetrating but not disagreeable odour. Specific gravity according to Muschenbroek 0.708; that of the yellowish kind according to Brissot = 0.845. It does not congeal at 0° Fahr.

By the slightest contact of a flaming body, naphtha takes fire, and burns with a very copious bluish yellow flame, a penetrating odour and much smoke. When distilled the colourless kind passes over unaltered, the coloured leaves

behind a small residue and becomes colourless. By long exposure to the air it is in part volatilized, and the residue is hardly to be distinguished from petroleum.

Naphtha communicates part of its aroma to water and alcohol, but appears to be insoluble in these fluids; it corrodes the corks of bottles in which it is kept; it combines with ether, the essential oils and resins. Pure ammonia and the caustic fixed alkalies unite with it into a saponule analogous to Starkey's soap.

The addition of concentrated sulphuric or nitric acid to naphtha causes a violent effervescence, and converts it into a solid resinous matter, soluble in alcohol.

The purest European naphtha comes from Monte Ciaro, near Piacenza, in Italy. This hill consists of horizontal beds of argillite, in which pits are sunk till the water comes in, after which the naphtha ouzes out of the sides and floats on the surface of the water, whence it is skimmed off every week.^b An inferior kind, often passing into petroleum, is procured at Monte Festino, not far from Modena, in the vicinity of which subterranean fires often break out.^c

But the most copious springs of naphtha with which we are acquainted are at Baku, near Derbend, on the north-west shore of the Caspian sea. The soil is a clayey marl, strongly effervescing with acids, and so thoroughly impregnated with naphtha that when turned up to the depth of a few inches it will take fire on the application of a lighted candle, and continue burning till it is purposely extinguished; the

^a Kirwan, ii. p. 42. Brechant, ii. p. 59. Gren, Systemat. Handbuch. iii. p. 2.

^c Ramuzini, Act. Lips. 1699.

^b Mem. Sci. 1736. p. 57.

flame is of a pale bluish yellow, and in calm weather rises to the height of several feet. The naphtha is procured by sinking pits, into which it percolates, and which are emptied from time to time. ^d

Naphtha is employed as an external application for strains and rheumatism; the Persians and Russians are said also to use it internally as a cordial. It enters also into the composition of some varnishes.

Var. 2. Petroleum, mineral tar, fossil tar, Barbadoes tar. *Pétrole. Steinohl, Erdohl, Bergohl.*

The colour of petroleum is reddish or brownish-black; it is more or less translucent; its consistence varies according to its temperature; when warm it is as fluid as common tar, but at 32° Fahr. it becomes very viscid: it is unctuous and clammy to the touch: it has a strong disagreeable odour and a pungent acid taste. Sp. gr. according to Briffon 0.878.

Petroleum is considerably inflammable, though by no means so readily as naphtha. Alcohol takes up some of its aroma and colouring matter. When distilled with water it comes over more fluid and clearer, approaching to naphtha: if distilled *per se* there first rises a portion of colourless naphtha, then an acidulous empyreumatic watery liquor, and lastly a thick brown empyreumatic oil; a shining coal remains in the retort, which after combustion leaves an earthy residue. Petroleum combines with the fat and essential oils, with the resins and camphor, and by long digestion dissolves sulphur: when rectified it also will dissolve caoutchouc. Sulphuric and nitric acids have the same effect upon it as on naphtha, but it is scarcely at all acted on by the alkalies.

At Kalurck, in Gallitzia, a kind of petroleum is found of a brown colour, which merits an accurate examination, as it was observed by M. Winterl to deposit, by exposure to the air, a quantity of acicular crystals. These crystals from their solubility in alcohol, and their tinging its flame of a green colour, were supposed by him to be borax. ^e

Petroleum appears to be found for the most part in coal-strata, or in secondary lime-stone. There is a spring of this substance at Coalbrookdale, in Shropshire, originating from a stratum of coal: at Pitchford, in the same county, is a coarse-grained sand-stone highly impregnated with it. It is also found in various parts of France, Italy, Switzerland, Hungary and

Sweden. A few miles from the naphtha wells at Baku, on the Caspian sea, are some very copious springs of petroleum, issuing from hillocks of the same substance hardened by exposure to the air; these springs sometimes take fire, and roll a flaming torrent into the sea, which floating on its surface often covers the water with a sheet of fire to a considerable distance. ^f

No country however produces so large a quantity of petroleum as the Birman empire in Asia: the town of Rainanghong is the centre of a small district in which there are 520 wells of petroleum in full activity. The country in which these are situated consists of a sandy loam resting upon alternate strata of sandstone and indurated clay; under these is a layer of pale blue argillaceous schistus impregnated with petroleum, of considerable thickness resting upon coal. The petroleum begins to flow into the well when it is sunk a few feet into the argillaceous schistus, and when it begins to fail the well is deepened. It is remarkable that no water ever penetrates into these wells. The annual quantity of petroleum produced by the whole district amounts to more than 400,000 hogsheds. ^g

The uses of petroleum where it abounds are very important. It serves the lower classes instead of oil for lamps, and when mixed with earth or ashes it answers the purpose of fuel. A composition of petroleum and resin is found to be an excellent material for covering woodwork and paying the bottoms of ships and boats, as it protects the timber from the attacks of insects or marine worms. Finally, when rectified by distillation, it is applicable to the same purposes as naphtha.

Sp. II. Solid Bitumen or Mineral Pitch.

Var. 1. Maltha. Cohesive mineral pitch. *Zabes erdpech.*

The colour of maltha is brownish black; it is opaque, and has little or no lustre; it is tough and soft so as to be impressed by the nail; its fracture is uneven: it has a strong disagreeable odour, acquires a polish when rubbed or cut with a knife, and does not stain the fingers. Sp. gr. from 1.45 to 2.06 ^h

Maltha when laid on a red hot iron immediately takes fire and burns with a large bright flame, leaving behind a small quantity of grey ashes. According to Kirwan ⁱ it consists of bitumen mixed with about 8 per cent of carbon and a little earth. It passes into the following variety.

^d Hist. des decouvertes Russes, ii. p. 215.

^e Crell's Chim. anal. 1788 p. 493. Journ. de Phys. xl p. 315.

^f Hanway's Trav. i. p. 263.

^g Cox in Asiatic Researches, vi.

^h Kirwan Mineral. ii. p. 45.

ⁱ Ibid. p. 522.

Var. 2. Asphalt, Jews' pitch. *Asphalte, Bitume solide* Haüy. *Schlackiges erdpech.*

The colour of asphalt is brownish black, rarely pure black: it occurs in mass, or disseminated or superficial or stalactitic: its fracture is small conchoidal with a brilliant resinous lustre: it is opaque, smooth and somewhat unctuous to the touch; does not stain or adhere to the fingers; is brittle and very easily broken. It gives out when rubbed a slight bituminous odour. Sp. gr. 1.07 to 1.65, according to Kirwan.

Asphalt when laid on a hot iron readily takes fire, and burns with a yellow flame and copious smoke, it swells but does not properly melt; after the flame has ceased there remains a light spongy coal, which by further combustion disappears, leaving a small quantity of ashes.

By dry distillation asphalt yields carburetted hydrogen gas, a light brown oil, or naphtha, and a little water slightly impregnated with ammonia: what remains in the retort is a shining coal of an iron grey colour, containing charcoal, a little earth with oxyd of iron, and sometimes of manganese.

100 grains of Albanian asphalt yield by this treatment, according to Klaproth,^k

- 36 cubic inches of carburetted hydrogen gas,
- 32 grains bituminous oil,
- 6 ——— water slightly impregnated with ammonia,
- 30 ——— charcoal,
- 7.5 ——— filix,
- 4.5 ——— alumine,
- 0.75 ——— lime,
- 1.25 ——— oxyd of iron,
- 0.5 ——— oxyd of manganese.

According to Kirwan's experiments of combustion by nitre, asphalt contains 31 per cent. of carbon.^l

Alcohol has no action on asphalt, but the fat and essential oils and ether, with some difficulty effect a solution of it. The best solvent however for this substance is rectified petroleum or naphtha; five parts of this will take up in the cold one part of asphalt, forming a saturated solution of a deep black colour, which upon evaporation leaves the asphalt in the form of a blackish brown shining varnish. The mineral acids have little or no action on asphalt, and the caustic fixed alkalies, even when boiled upon it, are incapable of dissolving it.^m

Asphalt is found at Morsfeld in the Palatinate, at Neufchatel in Switzerland, in large strata at

Avlona in Albania: it is found plentifully in detached pieces on the shores, or floating on the surface of the Dead Sea in Judea, hence called the Asphaltic lake. It abounds also in the islands of Barbadoes and Trinidad in the West Indies. In the latter of these islands there is a remarkable round plain about three miles in circumference, called the *Tar lake*, consisting entirely of a stratum of asphalt. From its colour and flatness it has the appearance at a little distance of a lake of water, but on a nearer approach it is observed to be divided in every direction by deep creeks from four to six feet wide, and generally full of water. The consistence and general appearance of the asphalt is that of pit coal, only the colour is rather greyer: it is very brittle and breaks into small cellular glossy fragments: some of the more elevated parts of the surface are covered with a thin brittle scoria. The thickness of the stratum is unknown. When it is cut into with an axe to the depth of a foot, it is softer and cohesive, and full of minute cells containing an oily fluid: a piece of this held to a candle makes a crackling noise, emitting small sparks with a vivid flame, but the combustion ceases the moment that the candle is withdrawn. When put into the fire it boils up for a long time without suffering much diminution, and after a continued heat the surface burns and forms a scoria, underneath which the rest remains in a semifluid state. A gentle heat renders it ductile, and when mixed with grease or common pitch it is used for paying the bottoms of ships, and is supposed to protect them from that pest of the West Indian seas, the teredo or borer.ⁿ

The uses of asphalt, besides that already mentioned, are as a varnish, and an essential part of the best wax or varnish for the use of engravers. Asphalt is often sophisticated by mixture with common pitch: it may however be readily distinguished from this latter, by having little or no smell, by its not adhering to the fingers, by its superior lustre and minute conchoidal fracture, by its burning without becoming fluid, and by its insolubility in alcohol.

Sp. III. Elastic Bitumen^o or Mineral Caoutchouc. *Pois mineral Elastique. Elastiches erdpech.*

Var. 1. Compact mineral Caoutchouc.

The colour of this substance is yellowish or reddish-brown, hyacinth-red, olive brown and blackish brown. It occurs massive, or mamillary, or stalactitic, or in globular distinct concretions.

^k Analyt. Ess. ii. p. 253.

^l Mineralog. ii. p. 523.

^m Klaproth Analyt. Ess. ii. p. 254.

ⁿ Anderson in Phil. Transf. vol. lxxix. p. 65.

^o Brochant, Hatchet in Linn. Transf. Fauj. St. Fond. in Ann. du Muséum National, No. 4.

It is sometimes viscid and adhering to the fingers, but generally more or less elastic passing into brittle, in which last state it is scarcely to be distinguished from asphalt: its colour becomes dark nearly in proportion to its hardness. It is translucent or translucent only at the edges: has a somewhat unctuous feel, and a slightly bituminous colour. Sp. gr. 0.905 to 1.233.

Mineral caoutchouc burns readily with a large flame and much smoke: when exposed to a gentle heat it melts, and is converted into petroleum or maltha, or asphalt, according to its previous consistence.

Rectified petroleum when digested upon this substance acquires a bright yellow colour, and causes the bitumen to swell and become transparent, but produces no other change: it is inalterable in oils and ether, and even when digested for a long time with boiling nitric acid or caustic potash: after having been melted however it exhibits the same chemical properties as petroleum.^p

Mineral caoutchouc has hitherto been found only in the Odin-mine near Castleton in Derbyshire, in secondary limestone accompanied by calcareous spar, fluor, blende, galena, pyrites and asphalt.

Var. 2. Suberiform mineral Caoutchouc.

Its colour is that of cream or pale ochre, but by exposure to the air it becomes of a pale reddish brown colour: its texture is very minutely cellular like cork, and in the cells (according to St. Fond) is often contained an empyreumatic acidulous liquor; by spontaneous decomposition it becomes friable and pulverulent; it is opaque, moderately elastic, and has an odour like that of leather. Sp. gr. 0.974 to 0.988.

This substance is not so readily inflammable as the preceding variety, and when applied to a lighted candle crackles as if it contained water. In its other properties it resembles the compact mineral caoutchouc.

It is found in a rivulet near the Odin-mine, in nodules and detached pieces, which upon being cut into often present a nucleus of compact caoutchouc, passing by insensible degrees to the present variety.

The elastic bitumen appears to be only a peculiar modification of petroleum in its passage to asphalt, and in all probability owes its elasticity to the moisture with which it is combined and to its cellular texture. It will perhaps on further investigation be found to differ in little or nothing from the cellular asphalt of Trinidad.

On account of the insolubility of mineral

caoutchouc there exists no proper analysis of it: from the results of its distillation and the incineration of the coaly residue it appears that 100 grains afford^a

38	cubic inches carburetted hydrogen gas,
4	———— carbonic acid gas,
73	grains bituminous oil,
1.5	—— acidulous water,
6.25	—— charcoal,
2.	—— lime,
1.5	—— filix,
0.75	—— oxyd of iron,
0.5	—— sulphat of lime,
0.25	—— alumine.

All the bitumens appear to be of vegetable origin, but for further remarks on this subject see COAL.

BITUMINOUS SHALE. See CLAY (Slaty.)

BITUMINOSER MERGELSHIEFER.

See MARL.

BITUMINOUS WOOD. See COAL.

BLACK-JACK. See ZINC.

BLACK-LEAD. See GRAPHIT.

BLACK-WADD. See MANGANESE.

BLEACHING. *Blanchissage*, Fr. *Bleichen*, Germ.

The process of bleaching consists of a series of operations, partly chemical and partly mechanical, to which vegetable and animal fibres are subjected for the purpose of discharging their natural colour, and thus rendering them white, either before or after they have been manufactured. Now as almost all the articles of cloathing are formed of vegetable or animal fibres, and as these are for the most part required to be made as white as possible, either to be worn in this state, or as preparatory to being dyed or printed, it is obvious that the art of bleaching is one of great importance. We shall therefore state as minutely as is consistent with the plan of this work the various methods of bleaching that have been put in practice, and endeavour to explain the reason of their more or less perfect success.

The substances upon which the bleacher is required to exercise his art are cotton, flax, hemp, wool and silk. The three former being of vegetable origin require a somewhat similar treatment, which in many particulars differs from that which is applicable to the two latter.

In order to form a correct idea of the rationale of the various bleaching processes, it is necessary to enquire into the nature of the colouring matter. It is to be regretted however that our information on this head is by no means so accurate as its

^p Klaproth, *Analyt. Ess.* ii. p. 83.

^a *Ibid*, p. 87.

importance requires. Mr. Kirwan indeed has made us acquainted with the properties of the colouring matter of linen, and for want of similar experiments on hemp and cotton, we must be satisfied for the present with concluding from analogy that the colour of these and all other vegetable fibres resides in a substance of nearly the same properties as is found in linen.

Mr. Kirwan's method of procuring the colouring matter was by adding diluted muriatic acid to an alkaline ley, which had been saturated with colouring matter by being boiled with brown linen yarn. * A copious flocculent sediment was thrown down, which when washed and drained on the filter was of a dark green colour and a soft clammy consistence like moist clay. By being further dried it became of a shining black and somewhat brittle, and when placed on a red-hot iron it burned with a yellow flame and black smoke, leaving a small coaly residue. The fresh precipitate appeared to be entirely insoluble in boiling water, or linseed oil or the essential oil of turpentine. To rectified alcohol it communicated a reddish hue, and was in a great measure dissolved; but on the addition of water the whole became milky and a white sediment was gradually deposited. It communicated a slight colour to the sulphuric, nitric and muriatic acids, but was not taken up in any perceptible quantity. The fixed alkalies both in a mild and caustic state, and ammonia when caustic, as well as the alkaline sulphurets, effected a complete solution of it and acquired a dark brown colour. Hence it appears to be a species of resinous extract.

This being premised, we shall now describe, first, the old method of bleaching, secondly, the alterations caused by the introduction of the oxymuriatic acid, and thirdly the more recent improvements suggested by M. Chaptal and others.

Cotton is seldom bleached till after it has been woven. When cotton cloth therefore comes into the bleacher's hands it contains, besides its proper colouring matter, a quantity of size or paste, with which the yarn is impregnated during the weaving. The first process to which it is subjected is *steeping*. For this purpose the cloth is placed in a vat and covered with lukewarm water, where it remains for about twenty-four hours. During this period a slight fermentation takes place, which loosens the adhesion of the paste and probably also disposes the colouring matter itself to be more easily removed by the succeeding operations.

The cloth being taken out of the steep is to be well washed in a current of clear water, and is then ready for the second process, or *boiling*. To effect this the goods are placed in a copper, with either pure water, or what is still better, a weak alkaline ley, and by means of a winch placed over the vessel are kept continually passing through the hot liquor, as long as it appears to extract any of the colouring matter; the cloth is afterwards taken out and well washed in clean water. To the operation of boiling succeeds *bucking*, which in fact is only another boiling in a stronger ley. The apparatus however is somewhat different, consisting of a large vat or bucking tub, connected by means of a pipe that enters its upper extremity with an iron boiler, and by means of a similar pipe passing from the bottom of the tub, with an iron reservoir in which a pump is fixed. The iron boiler is charged with a strong ley, and when it is warm a portion of it, by turning a stop-cock, is transferred by means of the pipe into the bucking-tub: here it falls first on the upper part of the cloth and presently penetrates the whole mass. After a time the cock of the lower pipe is turned and the ley, now almost cold, flows into the reservoir. A fresh quantity of hotter ley is then let into the tub from the boiler, and the contents of the receiver are thrown, by means of the pump, into the boiler again. Thus a continual circulation of the ley through the tub is effected for several hours, till the liquor becomes black, fetid, and almost of the consistence of treacle from the quantity of colouring extract that it has taken up. The cloth is then removed and well washed. The next process consists in *exposing it to the air*, which is done by spreading it out on the grass in the bleach-field, and keeping it always damp by throwing water on from time to time. To this another bucking succeeds, and thus these two processes alternate as long as any increase of whiteness is obtained. The last operation is that of *souring*. For this purpose a leaden cauldron is charged with water and as much sulphuric acid as will make the mixture almost as sour as lemon-juice; in this the cloth is to be immersed for some hours while cold, a fire is then made under the kettle, and the liquor is heated to be rather more than blood-warm: when the goods have been in the sours twenty-four hours they are taken out and immediately transferred to the river, where they are washed with particular care till all the acid is perfectly discharged: and the bleaching is now completed.

* Irish Acad. Transf. 1789.

The above was the old method of proceeding before the oxymuriatic acid came into use; and as far as concerned the discharge of the colouring matter it was certainly very effectual. If the leys however were too hot or too strong, the toughness of the cloth was liable to be injured, and even under the most favourable circumstances a great consumption of time necessarily ensued. The process could not be carried on in the four winter months; and from four to six buckings and as many weeks exposure to the air were required to bring cotton goods to their utmost whiteness.

The discovery of oxymuriatic acid was made by Scheele in the year 1774, and the efficacy of this elastic fluid in discharging the colour from vegetable substances was soon after noticed by the same able chemist; the discovery was communicated by him to Mr. Kirwan, who perceiving the probability of its being applicable to the art of bleaching, suggested this use of it to Mr. C. Taylor, at that time a partner in a calico manufactory near Manchester. By the exertion of this gentleman and his partners, "a whole piece of calico in the state received from the loom was, in the spring of 1788, actually bleached white and printed in permanent colours, and produced in the Manchester market ready for sale, having undergone all these operations in less than 48 hours.^b" M. Berthollet was in the meantime engaged in a course of similar experiments, the results of which he published in 1789,^c and from this period the use of the oxymuriatic acid was rapidly introduced into the bleacheries of England, France and Germany, with considerable and increasing success. The bleaching liquor of M. Berthollet consisted merely of water impregnated with oxymuriatic acid gas, but this was found to be subject to a number of inconveniences: it was troublesome in the preparation, was easily spoiled on exposure to the air on account of the volatility of the acid, its odour was so suffocating that it was with the utmost difficulty that the workmen could make use of it, and it not only discharged the natural colour of the cloth, but greatly weakened and impaired the colours communicated to it by dying, which confined its use to white goods. Some manufacturers at Javelle, in France, were induced to add a solution of caustic potash to the bleaching liquor, by which, though the rapidity of its action was in some degree diminished, yet its bad effects were very considerably mitigated; the process was thus how-

ever rendered much dearer on account of the additional cost of the alkali. In 1798, Mr. Tennant, of Glasgow, at length succeeded in the preparation of liquid oxymuriat of lime, and thus produced a bleaching liquor more safe and efficacious in every respect than the oxymuriat of potash, as well as greatly cheaper. The same skilful chemist has since carried the preparation of this article to perfection by procuring it in a solid state, in which it may be transported to any distance, and kept in barrels for almost any length of time without being injured.

In the new mode of bleaching cotton, all the processes as far as the first bucking are the same as before, but when this is completed the goods, instead of being laid on the grass to whiten, are immersed for about half an hour in a dilute solution of oxymuriat of lime; being then taken out and washed they are again boiled in an alkaline ley, and afterwards steeped in oxymuriat of lime, thus alternating these processes till the requisite whiteness is obtained. The cloth is then to go through the process of scouring as before, and finally is to be immersed in a weak ley of pearl ash or soap, to prevent a slight yellowish tinge which the use of oxymuriatic acid would otherwise occasion.

The *oxygenating* process of bleaching, by the use of oxymuriat of lime, appears to be perfect, whether we regard its safety, its expedition, or its cheapness, and the only further improvement to be required in the art, as far as the preparation of white goods is concerned, is to simplify and shorten the *bucking*, or those parts of the process in which the cloth is subjected to the action of alkali. A very ingenious and simple method of effecting this has been suggested by M. Chaptal, and the experiments which have been made appear to confirm the value of the proposed alteration. M. Chaptal's method consists in exposing the cloth when impregnated with caustic alkali to the action of steam raised to a somewhat higher temperature than that of boiling water.^d For this purpose a square or rectangular shallow boiler is firmly fixed in masonry, and a vault of stonework lined with lead is raised over it; at one end is a door sufficient to admit a man, made to fit very closely, and capable by the action of screws of being rendered steam-tight. Within the vault are fixed reels, by means of which either cloth or yarn can be wound off one on to the other, by a somewhat circuitous route, during which it is made to pass through the liquor in the boiler and is also exposed to the action of the steam.

^b Rees's Cyclopaedia, art. Bleaching.

^c An. de Chim. ii. p. 257.

^d O'Reilly sur le blanchiment.

The cloth or yarn being previously steeped for a few hours in an alkaline ley is wound upon one of the reels, and a quantity of ley is also poured into the boiler; the door of the vault is then secured and the fire under the boiler is lighted. This being done, the cloth is slowly transferred from one reel to the other, and afterwards returned to the former one, by means of a winch worked by hand or machinery on the outside of the vault. This being performed in a dense atmosphere of very hot steam, and the cloth in one part of its progress passing through the liquor in the boiler, the colouring matter of the cloth is much more speedily extracted than by the common process of bucking. Hence not only time is saved but the beating to which the goods are subjected in the wash-wheel, and by which their strength is in some degree injured, may be considerably lessened.

The colouring matter of flax and hemp is not only greater in quantity but appears to adhere more firmly than that of cotton; in consequence of which, though the general process for bleaching goods made of these materials is precisely the same as that which is employed for cotton, yet the strength and number of alkaline leys made use of is considerably greater. It is probable therefore that in the bleaching of linen, Chaptal's process (which we have just mentioned) might be adopted with the most decided advantage.

We have already noticed the experiments of Mr. Kirwan on the colouring matter of flax; this able chemist found that it was soluble not only in the pure caustic alkalies but also in the hydrofulphuretted alkalies. It is probable that this fact suggested to Mr. W. Higgins, of Dublin, the use of hydrofulphuret of lime instead of potash, an alteration which, if finally confirmed by experience, will be of the most serious advantage to the country by saving an enormous expence in an article for the whole of which we are dependent on foreigners. Mr. Higgins's method of bleaching Irish linen is the following. The linen as it comes from the loom is charged with the weaver's paste or dressing, to get rid of which the cloth is steeped in water for 48 hours and then well washed: it is afterwards immersed in a cold solution of hydrofulphuret of lime for 12 or 18 hours; being then washed and dried it is steeped in oxymuriat of lime for 12 hours. The linen is to be six times alternately immersed in each liquor, at the end of which operation it will be sufficiently white, and is then to be finished in the usual manner.

The rationale of the bleaching process for

vegetable fibres is not yet very satisfactorily made out; thus far however seems to be tolerably clear. The colouring matter of the cloth or yarn when it comes into the bleacher's hands consists of two portions, one soluble in alkali, the other not, or at least requiring for this purpose a ley of so great a strength as would also act on the vegetable fibre itself. When the soluble part is removed by the alkali, it is necessary either to expose the cloth for several days to the light and air, or to subject it to the action of oxymuriatic acid before a fresh portion of colouring matter can be rendered soluble in a ley of such a strength as it is safe to employ. It appears probable that the change in the colouring matter is entirely owing to an absorption of oxygen, and it would be a subject of curious enquiry to examine in what state the colouring matter is previous to oxygenation. It is not likely that it should be a perfect resinous extract, otherwise it ought to be entirely soluble in the first alkaline ley.

The *animal* fibres that are subjected to the bleaching process are wool and silk. These cannot be treated in the same manner as vegetable substances: a strong alkaline ley will dissolve them, and oxymuriatic acid will both weaken them and turn them yellow.

The colour of manufactured wool resides partly in its own oil, and partly in the greasy and mucilaginous applications which it receives in being prepared for the loom. Both the one and the other are easily got rid of by the action of fuller's earth and soap in the process of fulling. Fuller's earth is a very fine-grained absorbent earth, which by itself is capable of mixing rather than combining with vegetable or animal oils, and rendering them miscible with water; its action is found however to be increased by the addition of soap; and woollen cloth being beat in a fulling-mill with hot water, and a proper mixture of earth and soap, or of soap alone, and afterwards well washed and dried in the air, receives all the bleaching which it requires or is indeed capable of. It is then of a white colour, somewhat verging towards yellow; this last tinge may be made to disappear by the addition of a very small quantity of stone blue in the water in which the cloth is last washed, or by exposing it to the fumes of burning sulphur; by this latter method however it acquires a certain harshness of feel and is apt to turn very yellow when washed with soap.

Both the colour and harshness of raw silk depend entirely on a yellow varnish with which it is naturally covered. This varnish may be in

part removed by long boiling in simple water. It is considerably more soluble in alcohol, but the most effectual and expeditious way of clearing it is by putting it in a linen bag and boiling it for some hours in a solution of white soap in water, then rinsing it in clean water and repeating the process till it is quite white and exhibits the peculiar lustre of this beautiful substance. Some of the French chemists have endeavoured to lessen the consumption of soap by proposing various substitutes, but nothing is so effectual and expeditious as the purest white soap, and the article itself is so valuable as amply to repay this expence.

BLENDÉ. See ZINC (Ores of.)

BLOOD. This most important of all the animal fluids requires a pretty minute examination, both on account of the many interesting facts which its analysis presents, and as serving in some measure to illustrate the general history of animal matter, and also as it has engaged the attention of a multitude of excellent chemists with very great success and advantage to the science in general.

Blood when just drawn from the veins of all the warm-blooded animals (which includes man, most quadrupeds, birds, and the cetaceous fishes) is a smooth opaque uniform red liquid (crimson from the arteries), considerably denser than water, having a peculiar sub-nauseous odour, and a sweetish and somewhat saline taste. Its specific gravity is found to vary from about 1.053 to 1.126; its temperature in the living animal is usually from 96° to 100°.

The most remarkable circumstance in blood, and one in which it differs from every other fluid in nature, is the spontaneous coagulation which takes place not long after it is drawn, and which separates it into two portions, the coagulated part which is a red tough cake called the *crassamentum*, *clot*, or *cruor*, and the clear yellowish liquid in which the coagulum swims, called the *serum*. This spontaneous analysis has been the guide to chemical researches, and experiments have shewn both these substances to be further separable into several elementary principles, that is, the *crassamentum*, into the *red globules*, and the proper coagulable *gluten* or *fibrin*; and the serum into *albumen*, *gelatin* and several *salts*, all dissolved in a considerable quantity of *water*.

The circumstances that affect the spontaneous coagulation should first be noticed. From a healthy person the blood generally begins to stiffen in about five minutes, and becomes of

the consistence of jelly, some time after which a clear liquid will be seen to ouze out and gradually to occupy the sides and bottom of the vessel, whilst the red clot contracts in dimensions, encreases in firmness, and after several hours appears as a tough cup-like mass, retracted at the edges, on the surface exposed to the air of a much more florid red than when issuing from the vein, but all below the line in which it floats in the serum, of a dark blackish red. The cause of this change of colour has been with great probability supposed to be the action of the air, as will be presently mentioned.

There are three circumstances to which the spontaneous coagulation of blood has been attributed, namely, to cooling, to the air, and to rest. These have all been examined in a very satisfactory way by a late eminent physiologist.^a

If blood as it springs from the vein is received into a vessel set in a sharp freezing mixture, it does indeed congeal very speedily and becomes solid, but on being thawed it resumes its original fluidity, and *then* coagulates into serum and *crassamentum* as usual, and nearly in the usual time, beginning to reckon from its thawing. This shews most satisfactorily that coagulation of blood is not congelation, nor is it at all an effect of losing its natural heat by exposure to air.^b On the other hand if the blood is received into a cup set in water heated to about 105, it coagulates very completely, and even *sooner* than it would do if suffered to cool in the atmosphere.^c Hence it follows that the heat the most favourable to this process is not less than about the natural warmth of the blood. A greater heat will also promote this change.

The effect of rest alone on blood is shewn by simply intercepting a portion of blood in a large vein of a living animal by means of ligatures, and suffering it to remain in its natural situation in the vein for a given time. Under these circumstances Mr. Hewson found that the blood contained in the intercepted portion of vein (and therefore at rest, in the natural temperature, and excluded from air), instead of coagulating in about ten minutes remained partly fluid for upwards of three hours, and hence it follows that something besides mere rest must contribute to produce the speedy separation that takes place in blood that is drawn.

This appears to be in a considerable degree the action of the air, for if a portion of air is confined in contact with blood at rest in the vein of a living animal, coagulation *now* proceeds

^a Hewson on the Blood.

^b Hunter.

^c Hewson.

with much greater rapidity than when no air is present. However, Mr. Hewson also found that blood, issuing from a vein, and received in a phial which was corked up as soon as full, coagulated quite as soon as another portion of the same blood received in an open cup; and therefore, whatever effect the first impression of air may have upon fluid blood, its influence is not at all required during the whole time of coagulation.

Two circumstances also pointed out by the same acute physiologist, shew that the spontaneous coagulation of blood is not to be accounted for merely on common chemical principles, but depends very considerably on the state of the *living* animal.

If recent blood is received from the veins successively in different vessels, the last portion will be found to coagulate sooner than the first, and if a faintness comes on in the animal, the blood drawn in that state will flow with extreme difficulty, and will coagulate almost instantly. This is similar to what occurs in slaughtering beasts, it being commonly observed by butchers that the blood flows thicker, and at last hardly flows at all when life is just ebbing out. From this and other facts it appears that coagulation is essentially regulated by the vital powers of the animal at the time that it is losing blood from its vessels.

When blood is drawn from a person labouring under an acute inflammation, affecting the general system, it is usually much slower than usual in coagulating, and, if narrowly inspected, the surface instead of being of a florid red becomes transparent to a certain depth, then of a pearly whiteness, and at last, when the coagulation is complete, the crassamentum is covered with a very tough grey opaque crust often nearly to half its thickness, under which lie the red globules as usual. In this process nature makes a further analysis of the crassamentum, the grey opaque crust being the pure *fibrin* separated from the globules, which last, owing to the tardiness of coagulation, subside as usual, but separate, or nearly so, from the fibrin, which is longer held in solution, and therefore appears on the surface of the coagulum of its natural grey colour.

Several other facts are ascertained concerning the effects on coagulation of blood produced by a variety of circumstances affecting the powers and functions of the *living* animal, but these are out of the province of pure chemistry.

If blood is briskly stirred with a stick as it

flows from the vein, part of the fibrin collects pure about the stick, and the remainder will not coagulate by rest. Most of the neutral salts if stirred in fresh blood in considerable proportion, unite very uniformly with it and totally prevent the spontaneous coagulation. But if this salted blood is diluted with water the power of coagulation returns. Thus half an ounce of Glauber's salt mixed with six ounces of blood preserved its fluidity, but on being diluted with twice the quantity of water blood-warm, the whole soon coagulated very completely.^d The uncoagulated saline mixture on standing, gradually deposits the red particles, leaving a clear colourless liquor like mere serum in appearance, but proved still to contain the fibrin by its coagulating when diluted with water.

Nitre and some other salts render the blood florid.

The fibrin may be coagulated from the undiluted salted blood by applying a heat of about 120°. In doing this care must be taken not to raise the heat much higher, as this would also separate the albumen, which coagulates from the serum at about 160°, though it will not separate spontaneously at a lower temperature as the fibrin does. Indeed this circumstance forms almost the only ascertainable difference between the two substances. When both are coagulated together they cannot be separated.

To proceed with the chemical analysis of blood.

1. The crassamentum when completely coagulated and in its natural state, is of the consistence of very firm jelly, but still containing a good deal of serum, which it has entangled during its coagulation, and which oozes out copiously whenever the coagulum is cut into. The crassamentum is formed of two principal parts, the fibrin, and the red globular or colouring part. The former has already been mentioned to form the tough grey crust of inflamed blood, and also to be partly separated by stirring recent blood before it has time to coagulate. It is also obtained by washing out the red colouring part in the following way: put the whole coagulum in a linen cloth loosely tied up, and suffer a very small stream of water to drop on the outside of the bag, or else immerse the bag in cold water, at the same time pressing it very gently to and fro with the fingers. The water comes away of a fine claret-crimson, carrying with it the entangled serum, the colouring part, and every thing but the fibrin, which at last is left alone in the bag, and appears as a stringy

^d Hewson.

grey elastic mass, absolutely insoluble in water. Much patience is however required to succeed in this process, and only very little pressure should be used at first.

Fibrin^e when dried at a gentle heat loses about two-fifths of its weight, and thereby becomes hard and brittle. Before drying it has a remarkable toughness and elasticity, not unlike that of elastic gum. When scorched it shrinks and coils up like parchment. By dry distillation it gives a strongly ammoniacal liquid, a fetid thick oil, and much concrete carbonated ammonia. The coal which it leaves contains phosphat of lime, and is very difficultly incinerated. This earthy salt is detected by dissolving the soluble part of the coal in nitric acid and adding ammonia, which precipitates the phosphat of lime undecomposed. It contains no iron. Fibrin when moist and kept from drying soon putrefies in a warm air; under water it is gradually converted into ADIPOCIRE.

Water has no action upon it; when long boiled in water it becomes hard and transparent like horn. The fixed alkalies and concentrated solutions even of the alkaline earths, dissolve it in a boiling heat, with the evolution of ammonia, and produce a brown bitter saponaceous compound, decomposable by acids and metallic salts. Acids, even when dilute, dissolve it without difficulty. Nitric acid, if dilute and digested without heat, causes azotic gas to be given out, which in this case comes from the fibrin and not the acid; if concentrated and heated, the fibrin and nitric acid are mutually decomposed and evolve much carbonic and prussic acids, with nitrous gas and nitrous oxyd, and the residue contains oxalic acid. All the acid solutions of fibrin when evaporated nearly to dryness, give on cooling a stiff jelly. Neither fixed nor volatile oils act upon it. Alcohol hardens its texture very considerably and shrinks it.

From all these circumstances it is fully proved that the fibrin of blood bears the strongest resemblance to the *flesh* or *muscular fibre* of animals, and from its copious evolution of ammonia by distillation, and other characters, fibrin appears to contain a greater portion of azot than any other animal substance. See FIBRIN.

The red colouring part is singularly distinguished by being composed of an infinite multitude of globules, visible in a microscope of high power, the construction of each of which has been thought by Hewson to be that of an external vesicle, inclosing a sphere apparently solid; their diameter he estimates at about $\frac{1}{3000}$

of an inch. Dilution with water destroys the globular appearance, but not with serum, urine, and many saline solutions. Many other curious microscopical observations belong to this subject.

The red water used for washing the crassamentum and separating the fibrin, contains the whole of the red colouring matter. This water is slightly alkaline, as serum is, and when boiled a brown scum rises to the top, consisting chiefly of coagulated albumen, together with the proper colouring matter, but no method has yet been devised for totally separating these ingredients. The water after the scum has been removed is still red, and when evaporated gives to the last successive pellicles of brown scum, similar to that which is formed by the first boiling.^f The red globular part of blood alone contains the *iron* of this fluid, and as far as analysis has yet gone, this metal in the state of phosphat, and a certain admixture of serum, are all the constituents of this most curious substance.

The existence of iron in blood was first discovered by Menghini, and the experiments that simply shew its presence are obvious. Tincture of galls mixed with blood gives it an inky blackness, and if the crassamentum be dried it is strongly magnetical. But the precise state of this metal in the red colouring part is more difficult to be ascertained. To this object Fourcroy and Vauquelin made the following interesting research. On burning in a crucible the coagulated scum of the red liquor in which the crassamentum had been washed, they obtained a deep red ferrugineous powder, forming at first about $\frac{1}{200}$ of the blood employed, but still mixed with the coal of the albumen and other impurities. Very weak nitric acid dissolved out of the residue nearly all the iron, which solution, supersaturated with ammonia, gave a white precipitate. This again was put, while yet moist, into caustic potash, which redissolved most of the precipitate. The liquor now contained phosphat of potash, of ammonia and of iron, together with an excess of alkali, and by adding lime-water the presence of the phosphoric acid was proved by a precipitate of phosphat of lime. To confirm the possibility of a phosphat of iron and an excess of fixed alkali in the same liquid, they observed that there are two kinds of phosphat of iron, of which one is grey, insoluble in water, soluble in acids, and contains the phosphoric acid and the iron in mutual saturation; the other is of a reddish brown, less soluble in acids, and contains an excess of iron, so that it may be called

^e Fourcroy Syst. des Conn. Chim.

^f Fourcroy and Vauquelin.

a *sub-phosphat of iron*. Caustic alkalies added to the former phosphat only partially decompose it, and by taking away a portion of the phosphoric acid, reduce the remainder to the state of sub-phosphat of iron. This too agrees with the habitudes of some of the other phosphats with regard to partial decomposition. Now as the blood always contains an excess of soda, the abovementioned chemists ingeniously explain thereby the red colour of the blood, by supposing the phosphat of iron to be constantly kept by the soda in the state of sub-phosphat. They likewise endeavoured with success to produce a kind of artificial blood; as far as colour was concerned, by dissolving a sub-phosphat of iron in white of egg or in serum of blood, which was very readily effected even in the cold, and gave a blood-red fluid, the colour of which was further heightened by a small admixture of caustic fixed alkali.

The crassamentum of blood therefore, from what has preceded, is found to consist chiefly of the fibrin, and a phosphat of iron mixed intimately with a portion of serum into a peculiar red substance, which under the microscope exhibits an appearance of a vast multitude of globules, of a determinate shape and size.

2. The serum of blood is the clear yellow liquor in which the crassamentum floats after it is coagulated. Its taste is somewhat saline and peculiar, when agitated it froths readily and has a clammy feel to the fingers. Its specific gravity is about 1.027, according to Jurin and Muschenbroek. It immediately turns syrup of violets green, and gives other marks of an excess of alkali which analysis confirms. This alkali is soda. It readily unites with water, but by large dilution it turns milky.

When serum is heated to 160° or upwards, a large quantity of a whitish substance coagulates, so as almost entirely to solidify the serum, but on cutting up the coagulum a considerable proportion of a thinner watery liquid oozes out, which is called by physiologists the *serosity*. The coagulated mass, if gently heated for a little time, becomes hard, brittle and horny. It agrees so precisely in every chemical character with the white of egg and the other substances of this species, that it is justly reckoned as pure ALBUMEN, the properties of which are described under that article. If this albumen is calcined with a strong heat it burns with the usual products, and leaves in the coal a saline mixture consisting of muriat, phosphat, and carbonat of soda. These salts are foreign to what may be

considered as the true constituents of albumen, and must therefore be added to the list of component parts of blood, except the latter, which instead of a carbonat must be considered as naturally pure soda, having been doubtless carbonated during the calcination.

Alcohol added to serum also coagulates the albumen, as it does any other albuminous liquid. Acids do the same, the more completely as the acid is more concentrated, and after coagulating the albumen they unite with the excess of soda, forming the respective salts with this alkaline basis.

Another substance held in solution in the serum is *gelatin*. This is obtained by boiling diluted serum to coagulate the albumen, and then separating the clear liquid or serosity, evaporating it slowly nearly to dryness, and cooling. It will then appear as a stiff gelatinous mass, possessing all the properties of gelatin, though mixed with all the salts of the serum. Parmentier and Deyeux^s in their very elaborate analysis of blood, obtained the gelatin in a less exceptionable way. They heated some pure serum in a water bath, whereby the albumen was coagulated, and then instead of separating the solid from the fluid part, they continued the evaporation half an hour longer. The residue was white and cellular underneath, and each of these small cells contained a thick yellow transparent substance, which resembled in its properties the purest glue. The gelatin is only found in the serum, and was observed by these chemists to vary considerably in proportion in different persons and animals, without being obviously connected with any state of health or disease, or any kind of food or habitudes of the animal that furnished it.

Sulphur is another ingredient in blood, and is found in a minute quantity in the coagulated albumen, being indicated by blackening silver and producing the odour of sulphuretted hydrogen with acids. If the albumen of blood is heated in a silver vessel, the latter will become of a deep blackish-brown, in the same way that sulphur tarnishes polished silver. If nitrated silver be triturated with albumen, and the mixture digested for some time in a moderate heat, a black precipitate of sulphuretted silver is produced, from which the sulphur might readily be extracted. A similar indication of sulphur is shewn by the whites of boiled eggs, which every one knows will blacken a silver spoon almost immediately on touching it.

Lastly, the serosity or aqueous portion of the

serum deprived of its albumen by coagulation, if evaporated to dryness gives, besides gelatin and uncombined soda, a small quantity of muriat of soda, muriat of potash, phosphat of lime, and phosphat of ammonia, all of which may be detected by the proper chemical reagents.

The proportion of the constituent parts of blood is so extremely variable as probably to be scarcely the same in any two individuals. The varying quantity of crassamentum is the most palpable, and has long been observed by physiologists and medical observers. It appears to be the part the most intimately connected with the strength and vigour of bodily habit, and is the latest to return to its natural quantity after any great loss of blood, severe evacuation, deficient nutriment, or debilitating illness. It is also, *ceteris paribus*, more abundant in adult than in young animals.

It has been doubted whether the red colour of blood was owing to the iron which it contains, though the proportional quantity of this metal mixed with any colourless albuminous fluid, in the state of sub-phosphat with excess of alkali, is sufficient to produce as full a body of colour as that of blood. The ingenious arguments brought against this explanation of the cause of the colour by Dr. Wells,^a belong more to optics and the theory of colours than to chemistry, and we shall therefore not enter into them.

But there is another part of this subject properly belonging to chemical physiology, which should not be entirely unnoticed. This is the cause of the difference between *venous* and *arterial* blood. The blood contained in all the arteries of the body derived from the aorta, and also in the pulmonary veins, has a bright florid or vermilion colour, that of the other veins and the pulmonary artery, on the other hand, is of a dark black red; the former is termed the arterial, the latter the venous blood. The difference between the colour of the two is at once apparent when any deep wound has been inflicted, when the arterial blood will be as much distinguished by its more florid red, as by its manner of flowing by jerks corresponding with the pulse. The cause of this difference of colour is unquestionably owing to some change produced upon the venous blood as soon as received in the lungs, for the blood coming to the heart from the different veins of the body, goes from thence to the lungs by the pulmonary artery, *black-red*, and returns from the lungs by the pulmonary veins, *vermilion red*. This fact was observed long before the cause was accounted

for, though the circumstance of air being constantly admitted into the lungs made it probable that the air was in some way or other the cause of this change, and it had been thus conjectured by several physiologists.

The experiments of Dr. Priestley are the first which directly tended to confirm this very probable opinion, by shewing that the contact of air will produce the same change of colour out of the body as in it. This eminent philosopher took part of the crassamentum of the venous blood of a sheep,ⁱ laid it on a net of gauze or wire, and introduced it into different kinds of air. Common air soon gave it a florid red colour, but dephlogisticated (oxygen) air produced this change in a much more compleat and rapid manner. On the other hand the brightest red blood became presently black in hydrogen, nitrous gas, azot and any other air unfit for respiration. Now as common air is composed of oxygen and azot, and as the former gives a florid arterial colour to venous blood, but the latter only renders it darker, approaching to black, it follows that it is only the oxygenous part of the atmosphere which effects this change of colour in the lungs. From the same cause it is owing that the *surface* of venous crassamentum gradually becomes of a bright red in coagulation, whilst the under part is nearly black; and if the coagulum is turned upside down, the part that was at the bottom, being now in contact with air, gradually assumes the same florid hue.

The blood however is not in actual contact with the air in the lungs, being separated from it by the fine membrane (thinner than the thinnest bladder) which lines the air-cells and the coats of the extreme ramifying vessels of the pulmonary artery and veins. Hence it is requisite to do away the objection that might arise from this source against the opinion of the action of air on venous blood, to shew that the interposition of a thin membrane does not prevent their mutual action. Dr. Priestley accordingly found that when black blood was tied up in a bladder, moistened with serum and exposed to air, the change to florid colour was produced nearly as soon as when freely immersed in air.

Another objection to be removed was that, the colouring part of blood is in its natural state mixed with and immersed in serum, which must have some effect in separating it from the actual contact of air, but Dr. Priestley also found that the same change of colour happened when a piece of crassamentum was covered even

^a Phil. Trans. 1797.

ⁱ Experiments on Air, vol. iii.

to some inches with clear serum. On the other hand the slightest coating of oil, or even water, totally protected the black crassamentum from this action of air, so that there is something very unaccountable and surprizing in this supposed power of serum to transmit the influence of air. Milk is similar to serum in this respect.

The change of florid blood back to dark-coloured cannot however with so much certainty be inferred to be occasioned by any unrespirable air, for though it does take place under these circumstances, it will also happen when arterial blood is simply kept in a glass tube hermetically sealed for some days, and if kept in a warm temperature the black colour appears much sooner. Hassenfratz also found that arterial blood lost its florid colour and became of a purple red in a few days, even though kept in constant contact with oxygen gas.

It is still doubtful what is the precise action of oxygen on venous blood in changing it to arterial, but these, and a multitude of other curious enquiries on the chemical action of the gases on blood, belong more peculiarly to the subject of respiration.

All the stronger acids when added to blood darken its colour at the same time that they coagulate its albumen. Sulphuric acid chars it, as it does most vegetable and animal matter, with disengagement of sulphureous acid gas. Nitric acid disengages much azot, and the residue contains adipocire mixed with oxalic acid. The oxygenated muriatic acid immediately renders it as black as ink, a very curious circumstance which would not beforehand be expected considering the very opposite effect of oxygen gas.

The vegetable acids act on it but feebly, the gallic at once detects the presence of iron. Alkalies render blood more fluid, and redissolve the coagulum formed either spontaneously or by acids.

Blood very readily putrefies in a warm place, during which it becomes excessively fetid, the coagulum loses its texture, and finally much ammonia and carbonic acid are disengaged.

The effects of mere heat upon entire blood remains to be mentioned. If kept at a heat not exceeding that of boiling water it coagulates, becomes of a liver-brown, and by frequent stirring dries up into a black greasy-feeling paste, strongly attracted by the magnet and capable of being kept in a dry place without alteration for a great length of time. If gently moistened it becomes covered with efflores-

cences of carbonat of soda. If the dried blood is further heated in an open crucible it softens, puffs up, takes fire, and burns with a strong flame and a very fetid smell. The products of this combustion are first an ammoniacal water,^{*} then a pungent vapour of carbonated ammonia, then a dense yellow smoke, and after it some prussic acid, distinguishable by its smell like bitter almonds, and lastly jets of phosphoric flame, arising from the decomposition of the phosphoric salts by means of the carbon of the blood. Carbonat of soda is left behind, mixed with a black crystalline, nearly metallic oxyd of iron, a charcoal also ferrugineous, and phosphat of lime, with a little muriat of soda and of potash. If the dried blood is calcined in an earthen retort, the products are somewhat different but equally strongly ammoniacal, and the coal has a remarkably glistening metallic appearance, much resembling plumbago and very difficult to burn to ashes.

Blood is of no inconsiderable use out of the body. Some people use the blood of cattle largely as food mixed with meal of one kind or another. When intended for this purpose it is stirred briskly as it flows from the vein, whereby, as above mentioned, its coagulation is prevented, and it is then stirred into the meal and dried, or cooked in any other way. The coagulating property of blood renders it of considerable use in clarifying thick mucilaginous liquors. Cyder is sometimes fined in this method, being simply beat up cold with blood and put into a barrel. On standing a day, the entire coagulum of the blood, with the impurities of the cyder, are found lying at the bottom in a tough cake, and the liquor above is quite transparent and nearly colourless.[†]

Prussian blue is also made by first calcining blood with an alkali, whereby the prussic acid, which as above mentioned flies off during calcination *per se*, is detained in union with the alkali, and is afterwards made into PRUSSIAN BLUE by sulphat of iron. Lastly, blood is eminently useful as a manure, and as a material for generating NITRE.

BLOW-PIPE is a very important article of CHEMICAL APPARATUS. (See the Appendix.)

BLUE (Mountain) is a beautiful ore, a native Carbonat of COPPER.

BLUE (Prussian). See PRUSSIAN Blue.

BLUE (Saxon) is a solution of INDIGO in sulphuric acid, much used in some kinds of dying, especially of silk.

^{*} Fourcroy.

[†] Marshall, Rural Econ.

BOG-ORE of iron is a native mixed carbonat and phosphat of iron. See IRON.

BOLE. ^a *Bol*, Brochant and Emmerling. *Argilla bolus*, Werner.

The colour of this mineral is generally an obscure Isabella yellow, or reddish or whitish brown, it is also met with of a greyish yellow or flesh-red, and marked with black spots or dendritical figures. It is generally massive, seldom disseminated. It possesses a slight glimmering internal lustre. Its fracture is perfectly conchoidal. It flies when broken into irregular sharp-edged fragments. The dark coloured varieties are opaque, the lighter coloured are more or less translucent. It has a greasy feel, adheres strongly to the tongue, gives a shining streak, is soft and easily frangible. Sp. gr. 1.4 to 2.0.

When put into water it absorbs a portion with great eagerness, and then with a very sensible crackling noise breaks down into small fragments, but is not reduced to an impalpable powder. When finely pulverized and diffused through boiling water, it remains a much shorter time suspended in this fluid than any of the plastic clays are, and is totally separable by filtration.

When exposed to the action of the blowpipe it turns black and melts without addition into a porous, greenish-grey slag.

According to Bergman^b the Lemnian bole contains

47.0 siliceous powder,
5.4 carbonated lime,
6.2 carbonated magnesia,
21.0 alumine,
5.4 oxyd of iron,
17.0 water and volatile matter.

102.0

Bole occurs in beds of wakke at Strigau in Silesia, and in basalt at Scheibenberg in Saxony. It is also found in Tuscany and Sienna in Italy, and in the island Lemnos in the Archipelago.

The only use of bole at present is as a coarse red pigment; for which purpose it is calcined and levigated, and is vended in Germany under the names of Berlin and English red. Anciently it used to be an esteemed article in the materia medica, for which purpose not only the true bole but many of the bolar earths and clayey marls were made up into small cakes impressed on one side with the figure of a goat, or the

seal of the governor of Lemnos, &c. and kept in the druggists' shops under the general name of *Terra sigillata*.

BOLOGNIAN Stone. A species of native sulphat of barytes, from which a remarkable pyrophorus, or phosphorescent substance is prepared. See PHOSPHORI (*Solar*) and HEAVY-SPAR.

BOLT-HEAD an article of chemical apparatus, is a globular matrass with a long narrow neck. See the Appendix.

BOMBIC Acid. The natural juices of some insects have been found to contain an uncombined acid of no inconsiderable strength. One of these is the silk-worm. This was detected by Chaussier, from the circumstance of blue paper having been accidentally laid near these insects while changing to the chrysalis-state, being found covered with red spots, as if drops of acid had been spilled upon it.

To prepare it he bruised 15 ounces of silk-worm chrysalides in a mortar, and by expression through a linen cloth he obtained 9 ounces of a thick yellowish juice, strongly acid, but mixed with much animal mucilage and other matter. As this would soon putrify and destroy the acid he added first 2 ounces of alcohol and filtered the liquor, then added more alcohol as long as any precipitate was formed. This precipitate was animal mucilage and other impurities, insoluble in alcohol whilst the acid remained in solution with the spirit. A shorter and better method is simply to infuse the chrysalides in alcohol, which readily extracts the acid, becoming thereby of an orange colour, and afterwards this may be concentrated by a gentle heat, which will evaporate most of the spirit and leave the acid pure after filtration.

The bombic acid will unite with the alkalies and with many of the metals, forming salts, called in the modern nomenclature *bombiats*, but which are altogether unknown.

BORACIC ACID. ^c *Sedative Salt. Acide Boracique. Boraxsaure.*

This substance was first discovered in 1702, by Homberg, who by heating together in a subliming vessel a mixture of borax and sulphat of iron obtained a white crystalline salt, which from its supposed medical qualities he named *volatile narcotic salt of vitriol*, or *sedative salt*, imagining that it was produced from the vitriol. Lemery the son, however obtained the same salt soon after by treating borax with the sulphuric, nitrous, and muriatic acids, thus showing that

^a Emmerling, Brochant, Jameson.

^b Bergman's Ess.

^c Leonhardi's Macquer. Gren's Syst. Handb. Beaumé Chim. Exper. Fourcroy. Encyclop. Method art. Acide Boracique.

the vitriol in Homberg's experiment acted only in consequence of the acid which it contained. In 1788, Westrumb published his discovery of the presence of boracic acid in a mineral, which on that account has since been called *boracite*; and about the same time M. Hoëfer found this acid in the water of some of the Tuscan lakes. The water of lake Cherchiajo, in the territory of Sienna, which is supplied from a boiling hot spring of a sulphureous odour, contains about $\frac{1}{300}$ of boracic acid: that of the lake of Castel Nuovo contains a little more than $\frac{1}{150}$; and a hot spring near Sasso, in Sienna, deposits a concrete salt, consisting of boracic acid mixed with about $\frac{1}{8}$ of sulphat of manganese. ^a The term boracic acid was appropriated to this salt by Lavoisier and his associates at the general reformation of the chemical nomenclature.

Boracic acid may be prepared in two ways; either by direct sublimation or precipitation. The best method of obtaining it, according to the former of these processes, is the following. Take two parts of purified borax reduced to a fine powder, and mix them in a glass alembic with one part of sulphuric acid, previously diluted with an equal weight of water: on the application of a gentle heat the borax will dissolve, and at a boiling temperature there will first rise an acidulous water, and afterwards, when the mass in the alembic begins to grow thick, a light white glittering micaceous salt will collect in the capital, which is the boracic acid. As this salt sublimes only while the last portions of moisture are evaporating, it is necessary to return back repeatedly the acidulous water upon the mass in the alembic, in order to obtain the whole of the boracic acid; but this being a tedious operation and generally terminating in the fracture of the alembic, is at present but little practised.

The most expeditious and economical way of preparing the boracic acid is by precipitation. For this purpose take a boiling hot saturated solution of purified borax in water, and add to it by a little at a time so much sulphuric acid as to make the solution slightly acidulous. The liquor when cold will be found to have deposited a considerable quantity of thin crystalline plates of boracic acid, and more may be obtained by successive evaporation and cooling, till crystals of sulphated soda begin to make their appearance. The sulphuric acid is on several accounts preferable to any other for the decomposition of the borax; yet the nitric, muriatic, or even the acetous acids may be made use of.

^a Klaproth, Analyt. Ess. ii. p. 75.

The proportion of acid obtained by precipitation amounts, according to Beaumé, to nearly one half of the borax made use of; and it is this kind of boracic acid that has been employed by most chemists in their experiments on this substance. The precipitated acid is however by no means pure. Cadet ^e has clearly shown that after repeated lotions in cold water, and even solutions in alcohol, it retains a very sensible portion of the acid by which it has been precipitated; by which mixture its own properties are in many respects modified and altered. Beaumé's analysis renders it also probable that besides the precipitant the common boracic acid contains soda, and is perhaps only borat of soda with excess of acid, as borax is borat of soda with excess of alkali. 100 parts of boracic acid, according to this able chemist, contain

56 boracic acid,
14 an impure unfusible salt,
30 water of crystallization.

100

The most accurate, and upon the whole the most expeditious way of obtaining boracic acid in a state sufficiently pure for chemical experiment, is to decompose the borax by muriatic acid, and then fuse the precipitated salt in a silver crucible in order to drive off the portion of muriatic acid with which it is combined: the vitreous boracic acid being then finely pulverized, must be put into an alembic with water, and pure sublimed boracic acid will be obtained much more easily than by heating together borax and sulphuric acid.

Sublimed boracic acid is in the form of very minute thin plates, with a shining silvery lustre and remarkably voluminous in proportion to its weight. The crystallized acid has the same general appearance, only it is in larger plates and of considerably greater specific gravity. Pure boracic acid has not yet been the subject of any recorded experiments; the properties of the precipitated acidulous salt are the following.

Its taste is slightly subsaline; it reddens syrup of violets but exhibits very feeble acid characters: if prepared by the acetous, nitric or muriatic acids it lets them go in a vaporous or gaseous state when distilled with sulphuric acid. It is very sparingly soluble in cold water, and a pound troy of this fluid, even when boiling, will take up no more than 150 grains: as the water cools, it deposits in crystalline plates nearly the whole of the acid that it had dissolved. Alcohol takes

^e Mem. Acad. 1780, p. 583.

up a larger quantity of this salt than water does, and burns in consequence with a green flame; hence boracic acid has by some chemists been supposed to contain copper. But if a piece of paper is dipped in the alcoholic solution and then dried, it will burn with a deep yellow flame, it is therefore obvious that the green tinge in question is only caused by a mixture of the yellow flame of the boracic acid with the blue one of the alcohol. Other substances which tinge flame of a blue colour, such as sulphur and common salt, when mixed with boracic acid burn green.

When boracic acid is heated to redness in a silver crucible, it becomes first of a pasty consistence and then melts into a tenacious glass, perfectly colourless and transparent: by exposure to the air this glass becomes opalescent, but does not undergo any other change. It is soluble in hot water, and may be obtained by cooling, in the state of crystalline plates as before. When fused in an earthen crucible it dissolves some of the earth and forms a semi-transparent glass considerably less fusible than the pure acid; which when dissolved in water and evaporated becomes a gelatinous mass, superficially covered with a few crystals of boracic acid. Neither the oxygenizing nor deoxygenizing processes appear to have the smallest effect on this acid, and all attempts to decompose it, numerous as they have been, have not been attended with the smallest success.

Boracic acid unites in the moist way with the caustic alkalies, and by double affinity with the earths and metallic oxyds, except gold, platina, silver, bismuth and manganese. It is said to decompose nitrat of mercury by single affinity; but this is in all probability owing to the muriatic or sulphuric acid with which it is combined, for if it is prepared with nitric acid no such effect takes place.^f The order of its attractions in the humid way, according to Bergman, is, lime, barytes, magnesia, potash, soda, ammonia, zinc, iron, lead, tin, cobalt, copper, nickel, mercury and alumine. In solution it yields these bases to almost every other acid.

In the dry way boracic acid unites with the alkaline earths, phosphat of lime, the fixed alkalies, the metallic oxyds, flint and alumine; and on account of its great fixity and fusibility it dislodges all the acids, except the phosphoric, from their combinations.

It has no effect on the resins: but a saturated solution of it in boiling water is miscible with the gum-resins and oils into an imperfect sapo-

naceous compound. It is also said to retard the coagulation of milk.

The combinations of boracic acid with the salifiable bases are called *Borats*, a genus of salts hitherto very little known. Those, concerning which we are not wholly ignorant, are the following.

BORAT OF POTASH.

This salt is prepared by boiling boracic acid in a solution of caustic potash, either to exact saturation or so as to leave a slight excess of alkali; in this latter case it crystallizes in pretty large four-sided prisms, has a sub-alkaline taste, is permanent in the air, and when exposed to heat first swells and foams and then runs into a clear glass.

SUB-BORAT OF SODA. BORAX.

Borax is a saline substance that has hitherto been found only in Tibet.^g It is procured from a lake situated among the mountains, fifteen days journey from Tifoolumbo the capital, and entirely supplied by springs, no streams either falling into or flowing from it. The water has a salt taste and contains both borax and common salt, and on account of its elevated situation is frozen for a great part of the year. The edges and shallows of the lake are covered with a stratum of borax which is dug up in considerable masses, and the holes thus made are gradually filled by a fresh deposition: from the deeper parts of the lake common salt is procured. The borax in its rough state is called tincal, and is brought to Europe in the form of a brownish-grey impure amorphous salt, or in detached crystals about an inch in length, of a pale greenish hue, and in the form of compressed hexahedral prisms.

The purification of borax is an art which was first discovered by the Venetians, afterwards passed to the Dutch, and is now practised in great perfection by some English chemists. The process is as yet kept a secret, but in all probability consists of calcination, solution and crystallization. The crude borax is often covered with an oily or greasy matter to prevent it from efflorescing, and on this account is not easily acted on by hot water. It appears however that by exposing the tincal to a calcining heat lower than its point of fusion, the grease may be burnt off and the other inflammable impurities got rid of; the residue being then reduced to a fine powder and digested in boiling water, the saline parts will be dissolved, leaving most of the impurities behind.

Borax when quite pure is in colourless crys-

^f Cadet in Mem. Acad. 1780, p. 583.

^g Phil. Trans. lxxix. p. 97.

talline masses, very slightly efflorescent on exposure to the air. Its specific gravity, according to Kirwan, is 1.74. Its taste is somewhat sweetish and sensibly alkaline: it turns syrup of violets green, shewing therefore an excess of alkali in its composition. It contains by Kirwan's analysis

34 boracic acid,
17 soda,
47 water of crystallization.

98

Borax when exposed to a dry heat speedily dissolves in its water of crystallization, it then, as the moisture evaporates, becomes of an opaque white colour, and a voluminous spongy texture like burnt alum. If the heat is increased to a moderate redness it liquefies, and when cool appears as a colourless transparent glass. If poured out of the crucible in order to cool, it should be transferred as soon as it becomes solid to a covered basin or other proper vessel, for it always cracks and flies to pieces before it grows cold. Borax when thus fused is called glass of borax. By exposure to the air it acquires the appearance of chalcedony on account of the partial efflorescence that it undergoes. If made in a silver crucible, or if *hastily* melted in an earthen one, it is perfectly resolvable in water, but when kept fluid for a long time in a common crucible it dissolves a portion of the earth of the vessel and becomes little if at all soluble in water.

Crystallized borax requires twelve parts of water at the common temperature for its solution, but only six parts of boiling water; it therefore deposits crystals by mere cooling.

Borax is decomposable by all the mineral and vegetable acids when added to excess, the boracic acid being separated and the soda uniting with the other acid; but if only the *excess* of soda is combined with the other acid, the whole by evaporation and cooling forms a confusedly crystallized mass, in which the three ingredients appear to be in mutual combination. Borax will also dissolve and combine with nearly half its weight of boracic acid, forming *borat of soda*. In this salt the acid and alkaline parts completely saturate each other, so that it produces no change on syrup of violets, neither does it possess any longer an alkaline taste: it does not effloresce like common borax, nor are the forms of its crystals the same. The affinity of soda for boracic acid is not so great as that of barytes, strontian, lime and magnesia; these alkaline

earths therefore decompose borax, the pure alkali remaining in solution, and the earthy borates forming pulverulent insoluble salts. Potash is also capable of decomposing borax, but borat of potash being very soluble in soda, no precipitation takes place. Silica and alumina combine in the dry way with borax, the former into a transparent, the latter into an opaque glass. If the ingredients are in nearly equal proportions the glass is insoluble in the mineral acids, but if a considerable excess of borax is employed, the result is a soluble glass. Of this circumstance Mr. Chenevix has ingeniously taken advantage, by substituting borax for caustic potash in the analysis of the more refractory stony compounds, the use of the former salt being on many accounts much more convenient than that of the latter. Borax will also dissolve most of the metallic oxides, receiving from each of them peculiar tinges of colour.

The uses of borax are considerable: it is employed in the laboratory as a very active flux, and as producing a more perfectly limpid fusion than any other substance. For the same reason it is an ingredient in some of the finer kinds of glass; though its dearth prevents it from being employed so often as it otherwise might be to great advantage. Borax is also highly useful to the jewellers and goldsmiths as a flux for the solder by which pieces of gold and silver are cemented together; and in the East Indies it is employed in the moist way as a solvent for gum Lac.

BORAT OF AMMONIA.

Boracic acid digested with liquid ammonia deposits small rhomboidal octahedrons of a sharp and somewhat urinous taste. This salt changes the colour of syrup of violets green, shewing an excess of alkali: it undergoes no action from the air except a slight superficial efflorescence. When exposed to a melting heat, according to Wenzel, the ammonia flies off and the acid vitrifies, except a small portion that is volatilized with the water of crystallization. According however to Laffone, this salt melts entire into a greyish glass, which by solution in water gives the same kind of crystals as before its fusion. The fixed alkalies, both in the moist and dry way decompose it by combining with the acid.

BORAT OF LIME.

A solution of boracic acid mixed with lime water becomes immediately turbid, and after a while a pulverulent precipitate falls down, which is borat of lime. It is fusible at a full red heat into a white semitransparent glass. Two parts

of chalk with one of sedative salt, give by fusion in an earthen crucible a very hard yellow glass which strikes fire plentifully with steel: if the proportions are inverted, the result is a somewhat softer glass which often runs through the crucible. Three parts of earth of bones with one of sedative salt, gives a white porcellaneous mass of extreme hardness.^a

BORAT OF MAGNESIA.

Magnesia by long digestion with boracic acid is slowly dissolved, and the liquor by cooling deposits crystalline grains of borat of magnesia, which are exceedingly difficult of solution in water. Paper dipped in a solution of this salt and afterwards dried, burns with a yellowish-green flame. Alcohol in a great measure decomposes it, taking up the acid and leaving the earth behind. According to Achard¹ one part of sedative salt fused with two parts of carbonated magnesia affords a yellow porous vitrescent mass, which corrodes the crucible and gives fire with steel.

BORAT OF ALUMINE.

If newly precipitated undried earth of alum is digested with boracic acid, and the clear solution then evaporated, there will be deposited minute crystals mixed with a gummy substance of a remarkably styptic taste. This gummy matter appears to be chiefly borat of alumine. It is decomposed in the moist way by magnesia, lime and the alkalies, and by a melting heat runs into a glass. One part of dried earth of alum mixed with four parts of sedative salt, by exposure to a strong heat underwent little or no alteration, except that the inside of the crucible was studded with small white very brilliant crystals.^b

BORAX. (See the preceding article.)

BORACITE.¹ *Borazit, Wurfelstein.* *Magnésie boratée* of Haüy.

The colour of this mineral is yellowish, smoky or ash-grey, passing into greyish or greenish-white. It occurs in small cubic crystals truncated on the angles. The crystals are for the most part opaque, some are semitransparent, and a few of the smallest are entirely transparent. Their lustre internally is considerable and of the vitreous kind. The fracture is small and flat conchoidal, passing into uneven and splintery. The crystals are often more or less corroded, and then are easily pulverizable, but when perfect they are hard enough to give brisk and lively sparks with steel. Sp. gr. 2.56.

Boracite, when exposed to a full red heat, becomes opaque and loses about $\frac{1}{2}$ per cent. of its

weight, but undergoes no other change. When intensely heated in a clay crucible, it runs into a yellowish glass. It is entirely though with difficulty soluble in muriatic acid by long digestion. According to the analysis of Westrumb it consists of

68	boracic acid,
13.5	magnesia,
11.	lime,
1.	alumine
0.75	oxyd of iron,
2.	silica

96.25

Some later experiments however of Vauquelin make the proportion of lime to be much smaller, and it appears probable that the only essential ingredients of this mineral are magnesia and boracic acid.

Boracite is found near Luneburg in the duchy of Brunswick, lining the sides of a vein in a hill of gypsum. The crystals from their shape were known in the neighbourhood by the name of wurfelpath or cubic spar, and were supposed by some mineralogists to be a variety of quartz. The presence of boracic acid in them was not suspected till their analysis by Westrumb.

BONE. This important substance is found to compose a necessary part of the organized structure of all the mammalia, of birds, of the greater number of fishes, some of the reptiles, and the oviparous quadrupeds. In all, its use is to give firmness and support to the body, and to supply an unyielding fulcrum for the origin and insertion of most of the muscles subservient to locomotion. The same substance, a little modified in the proportion of its constituent parts, also furnishes many of the natural weapons of defence, as the teeth, tusks of all kinds, and the solid horns, such as the antlers of the stag or elk. On the whole, so great a similarity of composition is found in all these varieties of bone that a general description may first be given, and the bone of any quadruped (of the ox for instance) may be taken as an example of the whole genus.

It may be premised that there are at least two other great classes of organs serving for assault or defence, described in their proper places, one, the cuticular organs, nails, claws, and hoofs, which closely partake of the chemical nature of the softer and lighter Horns; and the other, the vast variety of crustaceous and testaceous coverings or calcareous habitations of

^a Achard, Mem. de l'Acad. de Berlin, 1799, p. 86. ¹ Ditto. ² Ditto. ³ Emmerling, Haüy, An. de Chim. ii.

insects, chiefly marine, which belong to the extensive chemical genus of SHELL.

Bone when first taken from the animal is moist and greasy to the feel, and if cylindrical it contains within its cavity a peculiar fat called *marrow*. When this is separated and the bone cleansed and exposed to a dry air it gradually dries, becomes more brittle and whiter, and under these circumstances may be kept for a great length of time without any further spontaneous change.

Bone, though to appearance quite dry and hard, is however essentially composed of certain *soft parts*, and of an earth or rather *earthy salt* besides other constituents of less importance, and the separation of these leading component parts is to be effected very compleatly by the proper use of water, the simplest and least exceptionable of all chemical reagents. It has long been known to common observation that rasped bone (hartshorn shavings for instance) boiled in water, furnish a good deal of clear strong jelly, and that uncooked bones chopped in pieces and added to the other materials for soup assist much during the boiling in giving richness and thickness to the liquor.

By the valuable experiments of Pelletier on procuring glue from bones,^a and those of Proust^b on the extended use of bone for human nutriment, the analysis by water has been carried to its greatest extent.

Cold water has very little action on bone, except in disposing it after a considerable time to a degree of putrefaction. When raw bones chopped in small pieces are put into scalding water, the first effect is to disengage a considerable quantity of oil (not marrow but a fat naturally combined with the substance of bone) which melts out by the heat and rises to the surface of the water, concreting when cold into a suetty mass which readily separates from the water. In this way, by only a quarter of an hour's boiling, Proust obtained from the knuckle and other joint bones of beef no less than one-fourth of their weight of this fuet, which was fine, white, and insipid. The shank part of the bone and the heavy flat bones yielded less of this fat.

Anatomists also constantly find this same oily matter sweating out of the bones of the skeleton, especially about the joint heads where the bones are lighter and much more open in their texture, and it requires long and very careful preparation entirely to get rid of it.

If the above chopped bones, freed from their

oil, are now ground down to a pretty fine paste, and again boiled with about ten times their weight of water for some hours, till nearly half the water is wasted, the remaining liquor will be of the consistence of thick soup, and when cold will concrete into a fine clear yellowish stiff jelly, nearly about the consistence that would be produced by dissolving one ounce of glue in thirty-one ounces of water, and extremely palatable and nutritious. At the bottom of the vessel the powdered bones are now found, much reduced in bulk and with little cohesion when rubbed between the fingers. The clear jelly, which should be poured off when hot, if further evaporated slowly towards dryness, and afterwards fully dried as in the manufacture of GLUE, affords a very firm good glue applicable to a number of purposes.

It is to be observed that any kind of bone however dry (if uncooked) yields abundance of this jelly by powerful boiling with water. So Pelletier obtained a pound of strong glue from 6 pounds of button-mold shavings, and $9\frac{1}{2}$ pounds of glue from 50 pounds of ivory shavings. Some jelly has been obtained even from bones kept for many centuries in cemeteries, provided they have been preserved above ground and not much exposed to moisture, so that this constituent part is very slow of decay.

Scarcely any boiling in *open* vessels however can totally separate the gelatin and perhaps the oil from the earth of bones, for in the above experiments the bony paste after repeated and long boiling was not absolutely dry and friable to the touch but had somewhat of a soapy feel, and when burned shewed some remains of the soft parts. But a much higher heat than the boiling point given to the water will completely produce this separation, and this is to be done in *Papin's digester*, as the inventor of this instrument actually found.

The gelly obtained in this way acquires however somewhat of a burnt taste and is less palatable, but the earthy residue is now perfectly crumbly and harsh to the fingers, and contains scarcely any trace of gelatin or animal fat.

Another *soft part* still remains to be mentioned. The discovery of it we owe to Mr. Hatchett, whose admirable experiments on the variety of hard animal organs, serving for support, protection and covering, have formed a most important addition to chemical physiology.* When fresh bone is immersed in any acid (the dilute muriatic or nitrous are best) a very slight effervescence is perceived, and it gradually

* Memoirs, tom. ii.

^b Journ. de Phys. tom. 53.

* Phil. Transf. for 1799 and 1800.

becomes soft, flexible, and porous, but retaining its original shape. The acid at the same time slowly dissolves out the gelatin (becoming thereby somewhat viscid and yellow) and also all the earthy part, so that at last nothing is left but an open reticulated cartilage or spongy cellular membrane. If the bone has been previously boiled the experiment will succeed as well, only there will remain less gelatin for the acid to dissolve, being already chiefly extracted by the water.

This spongy cartilage is essential to the constitution of all organized bones, and also of all shells and other hard coverings of animals, and it is the part first formed by nature, being as it were the outline or sketch of the bone, which afterwards receives solidity and strength by the gradual deposition of the earthy part. This rudimental cartilage is most conspicuous in the foetal state and in animals just born, whose bones are yet soft and flexible, but gradually acquire hardness and density by the increase of the earthy part in the process of ossification. Bony cartilage being insoluble both in water and in weak acids is therefore separable from the gelatin by the former menstruum, and from the earthy parts by the latter, but it cannot be readily exhibited in any other way than that above mentioned. Mr. Hatchett has found it to resemble coagulated *albumen*, and to differ from gelatin by the following decisive marks.

When dry it is semitransparent like horn and more or less brittle. In this state it so much resists the action of water that it may be boiled with this fluid for many days without sensibly diminishing; whereas the gelatin even of the hardest bones, as we have seen, is readily extracted by this fluid. The high heat of Papin's digester will however enable water to dissolve even coagulated albumen.

It is scarcely acted on by any acid if dilute, and without the assistance of heat, though by long maceration it becomes at last somewhat softened, and then dissolves in ammonia making a blood-red liquor. But if nitric acid is heated on this albuminous cartilage it is rapidly dissolved with discharge of much nitrous gas.

With caustic fixed alkali it is readily dissolved into a perfect animal soap, and during the process much ammonia is given out. Acids again separate the albumen from this soap unchanged. This character is much depended on by Mr. Hatchett as an argument for its affinity with albumen and difference from gelatin.

It is also extremely slow of putrefaction, remaining long unaltered even in warm and moist

situations, and in this too it strongly resembles coagulated albumen.

We may therefore enumerate as the *soft parts* of bone, gelatin, oil, albumen, and water.

A Swedish chemist, Gahn, was the first who discovered the true nature of the *earth* of bones. This earth is produced by burning bones of any kind in open vessels, or in the large way in the open air, till every thing volatile and inflammable is dissipated; and there then remains a hard porous white earthy substance, retaining the shape and size of the original bone, and generally amounting to from one-half to a third of its weight. This earth is easily reduced to powder, and suffers the most intense heat without further change. It is found to consist almost entirely of *PHOSPHAT of lime, with excess of lime*, or what is elegantly termed, according to Dr. Thompson's system of nomenclature, *Sub-phosphat of lime*, mixed with a small quantity of *sulphat* and of *carbonat of lime*. Messrs. Fourcroy and Vauquelin have likewise detected a small portion of *phosphat of magnesia* in the earth of the bones of all classes of animals except the human.

Many of the chemical properties of the earth of bone will be described under the article *PHOSPHAT of lime* and *PHOSPHORUS*, for the preparation of which last it is peculiarly convenient. For the analysis of bone the following particulars should be noticed.

Phosphat of lime exists in two states, in one with an excess of calcareous base as in the bone-ash, in the other with excess of phosphoric acid. When sulphuric acid is added to the bone-ash, only a partial decomposition takes place, and the phosphat by giving up a part of its lime to the sulphuric acid is changed to the *acidulous phosphat of lime*. This last, when dried and heated red hot, runs into a greyish white semi-opaque glass, and when strongly heated with charcoal the excess of acid is decomposed thereby, and the product is *phosphorus*, whilst the phosphat of lime, now deprived of its excess of acid, remains unchanged.

Phosphat of lime in any state is soluble with extreme ease in every acid, even by the carbonic when suspended in water and exposed to a stream of this acid gas; but it does not appear to be at all decomposed by any acid whose calcareous salt is a soluble one. Thus the nitric, muriatic and acetic acids, when digested with the earth of bones, simply dissolve the phosphat of lime, and again let it fall unchanged on the addition of any alkali, caustic or carbonated; and therefore the precipitate even

with the carbonated alkalies is not a carbonat of lime but simply the original phosphat, and will not effervesce with acids. This is a convenient circumstance in analysis, for if the phosphat of lime to be examined is mixed with carbonat of lime (as is the case in small quantity in bone-ash, and is indicated by a slight effervescence with acids) both are dissolved by the acid, and then caustic ammonia will precipitate only the phosphat of lime, and afterwards the lime belonging to the carbonat will be precipitated in a carbonated state by the addition of any carbonated alkali. The nitrous acid moderately diluted is a very convenient menstruum in the analysis of bone.

The phosphoric acid is indicated in another way. All the phosphoric alkaline and earthy salts, even the phosphat of lime, are completely decomposed by the salts of lead and mercury. Thus if nitrat or acetite of lead is dropped into a solution of phosphat of lime, all the phosphoric acid is separated and forms by double decomposition a precipitate of phosphat of lead, which is readily known by the following characters. When heated by the blowpipe on charcoal, it melts easily into a pearl-white globule, which immediately on discontinuing the flame cools into a button of a polyhedral form; but if the flame is continued, the phosphoric acid is gradually decomposed, and burns off with a luminous vapour smelling of phosphorus, and at last a globule of pure lead is left. Phosphat of mercury is precipitated as a white powder, which before the blowpipe on charcoal melts with effervescence and a green flame into a yellowish glass: by continuing the heat the mercury is volatilized first, and may be condensed in its metallic state on a plate of copper held over the vapor; the phosphoric acid then burns off into phosphorus as above mentioned. Phosphat of lead dried at a low red heat contains 22.5 per cent. of phosphoric acid.^d If sulphuric acid in any combination should happen to be present in the solution of phosphat of lime, it will also be decomposed by the nitrat of lead, and the precipitate will therefore be a mixture of sulphat and phosphat of lead. These are separable by dilute nitric acid, which will dissolve the phosphat but not the sulphat. This test is also of use to distinguish and separate the sulphat from the phosphat of lime, the latter being soluble in the acid, but not the former.

It has been mentioned that Messrs. Fourcroy and Vauquelin have detected a small portion of phosphat of magnesia in the bones of quadru-

peds and also of most other animals, except the human bone.^e This earthy salt is thus obtained: take calcined ox or horse bones in fine powder, treat them with an equal weight of sulphuric acid and mix thoroughly. After five or six days dilute the mass with ten times as much pure water, and strain through a linen cloth, pressing it at last to expel all the liquid, and pour fresh water on the white residue, press again and add this liquor to the other. Filter this acid liquor, which consists chiefly of phosphoric acid with acidulous phosphat of lime, of phosphat of magnesia combined with ammonia into a triple salt, the *ammoniaco-phosphat of magnesia*, together with some sulphat of lime. Add caustic ammonia in excess, which will precipitate only the phosphats of lime and magnesia. Wash the precipitate with cold water, and boil with a solution of pure potash, till no further ammoniacal smell arises. The potash has now completely decomposed the magnesian phosphat (but not the calcareous, on which none of the alkalies have any notable action) and the magnesia remains uncombined in the alkaline mixture and only mixed with the phosphat of lime. Wash out the remaining alkali, and add boiling acetic acid to the residue, which will dissolve the magnesia before it touches the phosphat of lime. This solution of acetite of magnesia treated with carbonat of soda and gently boiled gives a precipitate of carbonat of magnesia, which, if necessary, may be separated from any adhering lime by solution in sulphuric acid and crystallization.

By a number of comparative experiments the above mentioned chemists found that the calcined earth of ox-bones contained about $\frac{1}{40}$ of its weight of phosphat of magnesia (amounting to about $\frac{1}{80}$ of the unburnt bone, since by calcination it loses about half its weight); the calcined earth of horse and sheep bones gave about $\frac{1}{30}$ of this earthy phosphat; chicken and fish bone nearly the same as those of oxen, but there was no appreciable quantity in the human bone.

We may add the constituent parts of entire ox bone as given by these chemists.

Solid gelatin	- - -	51.
Phosphat of lime	- - -	37.7
Carbonat of lime	- - -	10.
Phosphat of magnesia	- - -	1.3
		100.0

This estimate is however imperfect, as no account is taken of the oil, nor of the albumen

^d Klaproth.

^e An. Chim. tom. 47.

of the membranous cartilage discovered by Mr. Hatchett. The earthy salts are probably accurate, and therefore the quantity of albumen and of oil, whatever they be, must be subtracted from that of the gelatin as here given.

The effect of heat on bones remains to be mentioned, for though the analysis by fire is peculiarly imperfect when animal or vegetable matter is the subject, several products valuable in the arts are furnished by this process. When bone is heated without addition in open air, it first becomes greasy and yellow, and gives out a watery vapour, to which succeeds a thick, dense, fetid smoke, which readily takes fire and burns with a most suffocating smoky ammoniacal smell. After some time it becomes black, brittle and carbonaceous, and if heated too suddenly splits and flies in every direction. At last, when a full red heat has been continued for a certain time, all the coal burns off, and nothing is left but the brittle sonorous white earthy phosphat, which retains the form of the original bone and all the porosity of its texture. This process of burning bones is performed near large towns or where bones are in quantity, for the sake of the white earth or *bone-ash*. For this purpose a large heap of the bones are built up in a kind of regular pile and are kindled on the windward side. When thoroughly lit, and when a few of them get hot enough to give out their oil freely, the heat which is produced is sufficient to continue and complete the burning without further assistance. A large heap continues many hours on fire before it is entirely calcined.

But several products are wasted in this way, which prove highly valuable when the burning takes place in close vessels and the distillation properly managed. For manufacture it is carried on in iron cylinders, for experiment a coated glass or an earthen retort will answer. When thus heated, bone yields with the first impression a limpid faintly-smelling water, which presently becomes *ammoniacal*, and contains a sensible quantity of carbonat of ammonia. With this (the heat being still gentle) a clear yellowish oil rises, pungent and not ungrateful to the smell. This should be carefully set apart and treated in a way to be presently mentioned. As the heat increases, this oil continues to come over, but now becomes brown, foul, and at last black, of a consistence increasing to that of melted pitch, strongly ammoniacal, and at the same time excessively fetid and smoaky. An abundance of gas escapes during this distillation, which is chiefly sulphuretted hydrogen, carburetted hy-

drogen, and carbonic acid. The condensed liquor in the receiver is both a water and an oil, each of which contains a large quantity of carbonat of ammonia, and the former holds some sebatic and prussic acids in solution. The ammonia is the most valuable part of these products, and is obtained pure by subsequent processes, described under the articles CARBONAT and MURIAT of ammonia. If the purer part of the oil is distilled *per se* out of a clean glass retort with only a gentle heat, the first portion of the oil rises much clearer than before, and by repeating this distillation out of clean vessels every time, taking only the first part that comes over, the oil becomes clear and limpid as water, with a very pungent ammoniacal smell, and so volatile as to waste quickly in the open air, or if kept in a bottle loosely corked. It is called from the inventor *Dippel's oil*. Much exposure to light turns it brown, and gives it somewhat of a smoaky smell. It is sometimes used in medicine.

If the distillation of the bones is stopped when the oil comes over very black, they are found drenched in a dark fetid oil, and penetrated with it. If the whole is then urged to redness in a close earthen or iron vessel, till every thing volatile has passed over, the earth of the bones remains so thoroughly impregnated with the fine charcoal of the oil as to be uniformly black throughout, glossy and brittle. When ground to a fine powder, mixed with size and made up into cakes, it forms the common *Ivory-black*, which from its greasy nature readily mixes with oil, and is the material for most of the ordinary black paints and varnishes.

A very fine black of the same kind is formed by charring ivory shavings in close vessels.

Bones are whitened by alternate exposure to wind, and moisture and sun. Salt water seems much to assist in this process, to judge by the extreme whiteness and cleanness of bones found on the sea shore. A previous boiling in a weak alkaline lye will much assist in extracting the natural oil, but this should be used with caution, otherwise the bones will soften and crumble down between the fingers. The oxymuriatic acid has also been applied with success to whitening the surface of bones.

The first action of all acids is to soften bone, in which state it readily absorbs any colouring matter, which sinks deeply into its substance. The bone afterwards hardens, and then will take a good polish.

The metallic solutions are very useful for colouring bone in a very deep and permanent

manner. Thus to give a fine green, dissolve verdigris in distilled vinegar, immerse the bones in the solution, and bury the whole in a dung-hill (closing the vessel well) or by any other gentle warmth for ten or twelve days. The bones are then found of a permanent green and will take a good polish. The TURQUOISE stone bone is found dyed of a native green by some mineral solution of copper. A good black is given by the solutions of silver or lead, or by boiling together equal parts of litharge and quick lime in water, and immersing the bones in it for several hours. The colour in these is heightened, and the polish increased by afterwards boiling them in nut-oil. Bones may also be made to take the vegetable dyes by first smearing them with dilute nitrous acid to open their texture, and then rubbing in the dye for some time.

TEETH are formed of an internal bony case, coated with a very hard white inorganic matter called the *Enamel*.

When a tooth coated with enamel is immersed in moderately dilute nitric or muriatic acid, ^f a weak effervescence takes place, and the enamel is entirely dissolved. The bony part is also acted on but not completely dissolved, for only the earth is taken up, and a cartilage retaining the shape of the tooth remains. In this it exactly resembles other bones, whilst the enamel differs from them all in being little else than an inorganic coating of phosphat of lime, not formed by deposition within the cells of an original cartilage, as in bone, but simply by a kind of exudation or deposition of this earth on the surface of the proper tooth.

When a tooth is immersed in concentrated sulphuric acid no action is at first perceived, but in about an hour small bubbles arise, the roots become blackened, and in twelve hours the enamel bursts, cracks and separates. Nitric and muriatic acids moderately diluted act instantly on the tooth with an evolution of small air-bubbles. The cartilage left undissolved is flexible, semitransparent, and easily divided. Boiling nitric acid acts strongly on the tooth with evolution of carbonic acid and azotic gasses. Mr. Pepys ^g found the enamel of the human tooth to contain 78 per cent. of phosphat of lime and 6 of carbonat of lime. They were separated in the analysis by adding to the nitrous solution, first, pure ammonia to precipitate the phosphat, and afterwards carbonat of ammonia to separate the carbonat of lime. The bone of teeth contained 58 per cent. of the phosphat

and 4 of the carbonat, together with 28 of gelatin dried at 212°. The entire teeth of adults, whose specific gravity is 2.272, yielded 64 per cent of phosphat of lime, 6 of carbonat of lime, and 20 of gelatin. Some difficulty however rises in estimating these proportions exactly, on account of the varying proportion of water according to the heat used. In the above analysis the phosphat was dried at a red heat, but the carbonat and gelatin at the heat of boiling water.

The uses of bone in different states are various and important. Its gelatin and fat extracted by water affords a cheap and wholesome nutriment. Bone itself is employed in a thousand ways, in turnery and a number of mechanical arts; all the refuse part yields by distillation a large quantity of ammonia, the basis of some very extensive chemical processes; a fine black pigment is made by its combustion in close vessels, and lastly the residuary earth is used as a material for cupels or assay crucibles, for some of the opaque white glasses, and gives phosphorus and a number of phosphoric salts by its decomposition. It is therefore on all accounts a most interesting object to the chemist and manufacturer.

BOVEY COAL. See COAL.

BOYLE's *Fuming Liquor* is the hydrosulphuret of ammonia formed by distillation. See SULPHURET.

BRAIN. The brain of animals exhibits some peculiarities in its chemical analysis, which, though they throw no light whatever on the explanation of the astonishing functions of this noble organ, deserve some notice here as a part of animal chemistry.

The experiments of modern chemists alone require attention, and especially those of Thouret made in 1790, ^h and some made by Fourcroy of a subsequent date.

Brain in its natural state is a soft pulp, with somewhat of a soapy feel, and little or no smell when fresh. Heated moderately, it dries simply by the loss of water, shrinks to about a fourth of its bulk, and then becomes a brownish-green, thick, tenacious mass. When dried as fully as possible without decomposition, it becomes solid; and breaks under the fingers like old cheese. If this is strongly heated in a crucible it gives out ammonia, puffs up, and melts into a black pitchy mass, and then takes fire and burns with much flame and a thick sharp smoke, leaving a coal difficult to be reduced to ashes. No naked alkali is left in the ash, but it shews by analysis

^f Hatchett.

^g Ph. Mag. vol. xvii.

^h Journ. de Phs. tom. 32—9.

some traces of phosphat of lime and soda. Brain, either in its natural state or gently dried without decomposition, unites very readily with water by rubbing, and forms an opaque uniform emulsive mass, which froths strongly by agitation, and does not separate from the water by filtration. In this it much resembles a solution of soap in water, but differs from the genuine soaps in containing no alkali, and hence it will not turn vegetable blues into green.

This emulsion of brain when heated nearly to boiling readily coagulates, and deposits its contents in white curdy grains. The clear liquid mixed with lime-water gives a precipitate of phosphat of lime, and hence contains a phosphated salt in solution. Acids and all calcareous salts added to the cerebral emulsion speedily curdle it. If an acid is employed, the clear liquor remaining after the coagulation contains lime, soda and ammonia, all united with the acid.

The nitric acid when dilute only coagulates the cerebral emulsion, but when concentrated it produces an effervescence, with evolution of much azotic gas, violent intumescence, heat, and subsequent production of nitrous gas, carbonic acid, and ammonia. The residue now contains a quantity of oxalic acid, one of the usual products of the distillation of nitric acid with almost any animal matter.

Muriatic acid simply coagulates the emulsion of brain, without inducing any very striking chemical change.

The caustic fixed alkalies even when cold, and much more when hot, unite speedily with brain into a soapy mass, at the same time disengaging much ammonia.

Under the article *Adipocire* was noticed the singular action of alcohol and the separation of a peculiar crystalline matter. A similar circumstance occurs here. When brain gently dried over a stove, or first mixed with water, coagulated by an acid, and the coagulum dried, is digested in a boiling heat with about twice its weight of alcohol, a solution is effected, which on cooling deposits a number of yellowish white crystalline blades. It requires two or three successive digestions with fresh alcohol entirely to exhaust this crystalline matter. Dried brain loses in the process about five-eighths of its weight, however on evaporating the alcoholic solution, no more than half the above quantity is collected, so that the remainder is probably only water intimately combined with the substance of brain, and not to be expelled by the previous drying. This singular crystalline matter

crushes under the finger with a kind of greasy consistence, is not melted, but only softened in the heat of boiling water; and when further heated it blackens, melts, and gives out a burnt and ammoniacal smell. In this respect it differs from spermaceti, which melts at 140° and cools again unchanged. Adipocire, to which also it has been likened, melts unaltered at about 83° . After the alcoholic solution of brain has deposited on cooling all the crystalline matter, the solution, evaporated, will give more of the same, but somewhat saltish and of a soapy consistence. This matter may be united with water by rubbing, into a kind of emulsion, which reddens litmus. A long maceration of brain in cold alcohol will dissolve a similar crystalline matter, and hence it is often found deposited in old spirituous anatomical preparations of the brain and nerves.

The substance of brain bears on the whole a considerable resemblance to albumen reduced to a kind of saponaceous state, perhaps by union with ammonia and much water; but the theory of the production of this crystalline matter is very obscure. Though it much resembles spermaceti, adipocire, and still more the crystalline matter of *biliary calculi* (described under that article) it somewhat differs from them all, particularly in being difficult of fusion. Its nature is considerably like that of a concrete oil, and hence Thouret was led to endeavour to extract oil from the brain by strong pressure, but without any success.

The spontaneous change which brain undergoes by putrefaction, and the very slow decomposition of this organ by spontaneous change are very singular circumstances, since it is well known to anatomists how great a loss of strength and cohesion in the texture of brain is suffered by keeping a very short time after death. Yet this same substance after this first change of texture appears to be perhaps the most indestructible of all the soft parts of the animal body. The memorable observations of Thouret on the exhumation of the burying ground of Les Innocents, at Paris, put this beyond a doubt. This observer remarks, that the bodies contained in this vast cemetery were found in different states; the greater number of them (which were those that had lain in heaps in the common receptacles of twelve or fifteen hundred corpses) were mostly converted to a kind of whitish soap, retaining the form of the different parts of the body. In all these the brain was in a state of very perfect preservation, and on opening the skull it was found in pretty large

lumps, filling from a third to a fourth of the cavity which it had occupied during life. In this state it was mostly soft, pulpy, breaking down between the fingers like mellow cheese, little offensive to the smell, and sometimes firmer and friable. In these globular masses, the original form of the brain, the divisions of its hemispheres, and the convoluted texture were still observable. Even the natural colour remained, so that on cutting it transversely the white medullary part would be distinguished from the browner cortical. Even where the period of inhumation had been so long as to destroy all the viscera and most of the muscles, the brain still remained.

BRANDSCHIEFER. See *CLAY slaty*.

BRANDY. This valuable spirit is produced by the distillation of wines of all kinds, and properly speaking by no other fermented liquor whatever. Under the article *ALCOHOL* we mentioned that the purely spirituous part of all fermented liquors appeared to be identically the same. Brandy, rum, corn spirits, &c. being the products of the first distillation from fermented liquors, and alcohol the purer part of each, separated by a subsequent process.

Brandy is prepared in many of the wine countries of Europe, and with particular excellence in many parts of the center and south of France. The necessary process is extremely simple, being nothing more than a well regulated distillation of wine without addition, from suitable vessels, but to alter or improve the colour and flavour various substances are added to the spirit after distillation. The manufactory is technically called in France *Brulerie*, and the makers, *Bruleurs d'Eau de Vie*.

Though every wine will give a certain portion of brandy by distillation, some are much preferable to others. In general the strong heavy wines yield the most spirit, giving nearly a fourth of good proof spirit, whilst some of the light thin wines furnish no more than about a fifteenth. If the quantity is less than a sixth it will hardly repay the expence of distillation.

The distilling apparatus is composed of three parts, the *alembic* or boiler, the *capital* which sits on the top of the boiler to receive the spirituous vapour, and the *serpentine* or *worm*, a convoluted pipe fitting to the beak of the alembic and immersed in a large tub of water, to cool the vapour of the spirit, and condense it into a liquor which flows out at the bottom.

The alembic^a is a cylindrical copper boiler, about 30 inches (French) in height, and 24 in

diameter, flattened at the bottom to present a greater surface to the fuel, and drawn out into a neck at the top about 2 inches high, and only 9 or 10 in diameter. It holds about 320 quarts. The capital, which sits on the neck of the alembic has the form nearly of a very flattened cone with the apex downwards, and truncated where it joins the alembic. Its diameter is here of course a trifle more than that of the neck of the alembic over which it sits. Above, it is about 7 or 8 inches wide. A tube or beak projects laterally from the lower part of the capital to convey the vapour into the pewter serpentine, which makes six or seven turns before it reaches the bottom of the large tub of water in which it is immersed. The diameter of the worm is about an inch and a half at the part joining the beak of the serpentine, and gradually lessens to one inch at the bottom. The alembic is built into brick-work, which covers the whole except the bottom, which hangs over the fire, and the neck where it joins the capital. Beneath is the fire, generally wood, enclosed in the usual manner of fixed boilers, and furnished with an ash-pit and register to damp the fire at pleasure.

In the distillery, the alembic is first filled to about five-sixths of its capacity with wine, and the fire kindled. When the wine nearly boils, the capital is put on, and all the joinings luted with a mixture of clay and ashes. A thin stream of brandy soon pours out from the lower end of the worm pipe into a cask set to receive it. The fire at first is slow, otherwise the wine boils up into the capital, and part passes into the worm and fouls the spirit: and as a general rule, the slower the distillation the finer and stronger is the spirit obtained. What first comes over is the richest in flavour and the strongest spirit, for as alcohol boils at a much lower temperature than water, the greater part of the spirit comes over but little diluted with water; but the liquor gradually decreases in strength as the process continues, and at last contains so little spirit as to be entirely unflammable, and almost void of taste. When this happens, the fire is put out, and the contents left in the alembic, consisting of the watery lees of the wine, are thrown away as useless. The wine is known to be entirely exhausted of spirit, by taking a little of the distilled liquor then coming over, putting it on the hot part of the capital and applying a lighted stick, if the vapour does not catch fire the liquor is little else than water.

As the brandy comes over with a constantly

^a *Encycl. Meth. art. Alcool & Distillateur Liquoriste.* Beaumé & Rosier in *J. de Phys.* tom. 12 & 13.

decreasing strength, a distinction is always made between the former and the latter part of the product, and the two liquors kept apart. The first is fit for immediate use, the last, which is called *seconde* or *petite eau*, is redistilled in the next process. It answers to the *feints* of the British distillers. The precise time at which the second portion is begun to be collected is arbitrary, and differs in different countries. In some countries it is determined by the proportion of spirit already obtained to that of the wine put into the alembic; in other places, by a certain specific gravity; in Spain and Portugal, as in rum-making in Jamaica, the sinking of olive oil in the spirit is the established proof, for the less the specific gravity of the spirit the greater is its strength. It takes about nine or ten hours to run off the quantity above mentioned.

Brandy is naturally clear and colourless as water, for the colour which it has in commerce is given partly by the casks in which it is kept, but chiefly by certain additions to the spirit, such as saunders wood, burnt sugar, &c. and which appear to do neither good nor harm to the quality of the spirit.

There are several ways of judging of the strength of the spirit. Many of these are mentioned under the article ALCOHOL, which see. The dealers also judge a good deal of the quality of the spirit by the appearance of the bubbles which arise when brandy is strongly shaken in a phial, by their size and degree of permanence. For this purpose a strong phial is filled three-quarters with the spirit, and strongly knocked against the knee to form a froth, and those that are in the habit of examining samples put much confidence in this test, combined with that of the hydrometer to ascertain the specific gravity, and the smell and taste. This former test however is often fallacious, being liable to be imitated by certain well-known additions.

The strength of the spirit of course depends on the strength of the wine from which it is made, and the perfection of the fermentation which it has undergone. The quantity of saccharine mucilage in the grape-juice, the basis of fermentation, varies very much according to the soil, climate, and season, the kind of fruit and time of gathering. In general it is most abundant in the warmest climates and seasons, and is much increased by lateness in gathering the crop. Such wines require a long and complete fermentation, and then they are rich, full-bodied and spirituous. The very strongest wines yield about a third of their weight of proof-brandy;

on the other hand the weakest wines, though well fermented and perfect liquors, give only about a fifteenth. Chaptal states the general average of product from the wines of the south of France and Spain to be about a fourth.^b

The principal differences in the quality of brandies are *strength* or quantity of alcohol, and *flavour*, which last seems to depend on several principles contained in the spirit which rise with it on distillation. Besides this, there are generally several foreign additions made to it by the manufacturer, which do not belong to the present subject.

The *empyreuma*, or burnt taste, is a frequent defect in all distilled liquors, and very notably so in the common brandies. This is scarcely ever found in the first products of the distillation of wine, as the spirit begins to rise at a much lower temperature than afterwards, but as the process advances and the wine requires a greater heat for boiling, part of it undergoes that alteration which gives the empyreumatic flavour. It is also more prevalent where the alembic is too high and deep, so that part of the spirit is constantly falling back into the still, and the process is thus protracted to a great length of time. It may also at any time be given by increasing the heat and boiling the wine with too much vehemence. Chaptal, with some probability, attributes the source of this flavour to some decomposition of the *malic* acid contained more or less in almost all wines, and which partly rises with the distilled spirit. This acid is detected by forming insoluble salts with lead, silver, mercury and lime, by not being crystallizable, and by other tests described under that article, and it is found most abundantly in thin, ill-fermented wines, and in cyder, perry, and liquors made from harsh fruits. On the other hand the full-bodied rich wines are the most free from this acid. The more abundant the malic acid, the more will the spirit be acrid and empyreumatic, and that which is obtained towards the last contains enough of the acid to be very sensible to chemical tests. The addition of chalk, alkali, or lime-water to the wine keeps down the acid very effectually, and renders the spirit much purer, but from some cause not easy to understand it remarkably diminishes the total quantity of product. From the caprice of fashion however this empyreumatic flavour, though disliked by the most delicate judges in the wine-countries, has become an excellence in some exported brandies,^c and therefore must accordingly be given by the manufacturer.

^b An. Chim. tom. 37.

^c Chaptal.

Another substance which gives a very strong and generally a very unpleasant flavour to brandy, appears to be an essential oil of a peculiar nature, and found most abundantly in the richest and fullest-bodied wines. It is certainly altered in the process of distillation, and rendered nauseous from being originally grateful and aromatic. When spirit charged with this oil is rubbed in the hands, as it evaporates it leaves its peculiar smell, which resembles the breath of habitual drunkards. The very rich wines, particularly some of the Spanish, occasionally are so full of this oil as to deposit it in quantity on the capital of the alembic, where, when cold, it concretes into a strong, nauseous substance, of the consistence of pomatum.^d Spirits distilled with oils previously added to them in the alembic, such as the malt-spirit brandies or imitations of brandy, are very liable to acquire a nauseous flavour. Brandy distilled from these oily wines is in fact a saturated solution of essential oil in alcohol, and like any artificial solution of the kind it becomes milky on the addition of water, which, by uniting with the spirit separates most of the oil in minute globules. Hence the addition of water to these oily brandies, with a cautious redistillation much improves the quality of the spirit.

Wine contains a peculiar *aroma* or perfume, but whether this can at all be considered as a peculiar principle distinct from the essential oil, is a matter of doubt. Yet from the delicate and perishable nature of this aroma, and the permanence of the oil, perhaps some ground of distinction is obtained. Some of this delicate aroma appears to pass into the first distilled spirit which it yields, though somewhat altered; but a second rectification destroys it altogether.

The manufacture of brandy in other countries very much resembles that of France, being equally simple, and the apparatus essentially the same. In Spain the principal brandy distilleries are in Catalonia. The wine yields on an average about a fifth of spirit of olive-oil proof (or that in which this oil sinks) and about as much of an inferior spirit for redistillation. When the wines are old, heavy and oily, and a fine clear spirit is wanted at once, water is added to it in the alembic before distillation to separate and keep down the oil. In Portugal the oil-proof is also established, and the wines are mostly full-bodied and oily.

An inferior kind of brandy is made from the *marc* of grapes, or the residue of the fruit after the juice has been made to flow out by the

action of the press. This still retains enough of the grape juice to be readily brought into fermentation, and consequently to be able to yield a spirit by distillation. In Swisserland it is thus managed. Wine casks are filled with the fresh marc quite full, and pressed down by trampling to make it lie close, which prevents it from moulding. The casks are then headed, and the bung-holes and joinings closed up with clay. In two or three days the fermentation begins, the marc heats, and when the first working has subsided and it has acquired an agreeable vinous smell (which happens in from two to five weeks according to the season) it is fit for distillation. In distilling it, the alembic may be filled quite to the top with the marc, for as it lies loose and takes up much room, there is no danger of boiling over, water is then added, just sufficient to wet it thoroughly, and a very moderate fire kept up during the whole process. This precaution is particularly requisite here to prevent the lowest part of the contents of the alembic from burning and giving a very unpleasant taste to the spirit. Thirty-two cubic feet of marc are estimated to give about ten gallons of spirit, which however is rectified before it becomes very palatable. If the marc is not wanted immediately, it will keep without spoiling in well stopped casks for two, three, or even four months.

Beaumé in his experiments on distillation suggests two good improvements in the above process, whereby a good spirit may be obtained from the marc by the first distillation. One is by immersing the alembic in a water bath, which effectually regulates the heat and prevents the possibility of any of the marc being scorched and hurting the flavour of the spirit. Another, and more convenient in the large way, is to prevent any of the marc from actually touching the bottom of the alembic, by interposing a kind of wicker cradle on which it rests, and whereby it is raised an inch or two from the fire. Water is added as before, and its vapour penetrating the marc extracts and carries over all the spirit by a gentle boiling.

The improved alembic and refrigeratory are described in the Appendix (article *Apparatus*.) See also ALCOHOL, WINE, and DISTILLED SPIRITS.

BRASS or *Latten*. *Laiton*, Fr. *Messing*, G.

This very important alloy is a mixture of copper and zinc in various proportions, so intimately united as to form a homogeneous malleable yellow metal, applicable to a vast variety

of purposes and capable of being wrought with the greatest facility.

It is not easy to obtain a perfect union of zinc and copper by mere fusion in open vessels, for at a heat less than is required to melt the copper, the zinc readily takes fire and much of it burns off before it has time to mix with the other metal, so that the proportion of zinc is constantly lessening by volatilization. Even after both metals are fused, the zinc continues to burn off in uncovered vessels, and at last scarcely any thing but copper would be left. In order therefore to combine copper most intimately with zinc, and yet to preserve its malleability, the ingenious process of *cementation* has been resorted to in the manufacture of brass, which is performed by heating in a covered pot alternate layers of copper in small pieces, with zinc ore and charcoal, and continuing the fire till the copper is thoroughly impregnated with the zinc.

Zinc being a volatile metal can only be procured from its ores by sublimation; the process for obtaining it (which will be described more at length under that article) being to heat strongly a mixture of its ore with charcoal in a vessel closed on all sides, except where it admits a tube, the lower end of which dips in water: as soon as the charcoal reduces the oxyd, the metal rises in vapour through the tube and condenses in the water below. A similar reduction takes place in brass-making, only the vapour of the zinc instead of being conveyed out of the crucible in which it is formed, unites with the copper enclosed in the same vessel, and the whole melts down into brass. A less heat is required in brass-making than that which fuses copper, the zinc being able to penetrate the copper when thoroughly red hot, and melting it down as soon as it becomes brass.

Brass is manufactured in many countries, but no where more extensively and better than in England, in which both the materials are in great abundance. The ores of zinc are several species of *calamine* and of *blende*, called by the miners *Black-Jack*, which are found abundantly in Devonshire, Derbyshire, and North-Wales, generally accompanying lead ores. These are chiefly oxyds or carbonated oxyds of zinc, and require a previous calcination before they are fit for brass-making.

At Holywell, in Flintshire, the calamine which is received raw from the mines in the neighbourhood, is first pounded in a stamping mill, and then washed and sifted in order to

separate the lead, with which it is largely admixed. It is then calcined on a broad shallow brick hearth, over an oven heated to redness, and frequently stirred for some hours. In some places a conical pile is composed of horizontal layers of calamine alternating with layers of charcoal, the whole resting on a layer of wood in large pieces, with sufficient intervals for the draught of air. It is then kindled, and the stack continues to burn till the calamine is thoroughly calcined. The calamine thus prepared is then ground in a mill, and at the same time mixed with about a third or a fourth part of charcoal, and is then ready for the brass furnace. In some places pit-coal is ground with the calamine instead of charcoal, but this is found to injure the malleability of the brass obtained.

The brass-furnace^a has the form of the frustum of a hollow cone, or a cone with the apex cut off horizontally. At the bottom of the furnace is a circular grate or perforated iron plate, coated with clay and horse-dung, to defend it from the action of the fire. The crucibles stand upon the circular plate, forming a circular row with one in the middle. The fuel, which in England is coal, is thrown round the crucibles, being let down through the upper opening or smaller end of the cone: over this opening is a perforated cover made of fire-bricks and clay, and kept together with bars of iron so as to fit closely. This cover serves to regulate the heat in the following manner: the draught of air is formed through an under-ground vault to the ash-hole, thence through the grate and round the crucibles, and through the smaller upper opening into an area where the workmen stand, which is covered by a large dome and a chimney to convey the smoke into the outer air. When the draught is the strongest, and the heat is required of the greatest intensity, the cover is entirely removed and the flame then draws through the upper opening of the furnace to a considerable height into the outer brick dome; when the heat is to be lessened the cover is put on, which intercepts more or less of the draught from the furnace, as more or fewer of the holes of the cover are left unstopped.

The crucibles are charged with the mixed calamine and charcoal, together with copper clippings and refuse bits of various kinds, and sometimes brass clippings also, most of which are previously melted and run into a small sunk cistern of water through a kind of cullender,

^a Keir in a note to the article *Brass* in Macquer's Chem. Dict.

which divides the metal into globules, like shot. Powdered charcoal is put over all, and the crucibles are then covered and luted up with a mixture of clay or loam and horse-dung.

The time required for heating the crucibles and completing the process varies considerably in different works, being determined by custom, by the quantity of materials, the size of the crucibles, and especially the nature of the calamine. In the great way from ten to twenty-four hours are required. At Holywell, in Flintshire, about twenty-four hours are taken.

During the process, and especially towards the latter end, part of the reduced zinc which escapes absorption by the copper, finds its way in vapour through the luting of the crucible-lids, and burns around them with the beautiful blue flame and dense white smoke peculiar to this metal.

The heat required for brass-making is somewhat less than what would be necessary to melt large masses of copper, brass being the more fusible of the two, and, as it should seem, the vapour of zinc being able to penetrate copper as soon as it is softened by a full red heat. When the brass is judged to be complete, and the saturation of the copper with zinc to be as high as possible, the heat is increased to melt the whole down into one clean mass at the bottom, the crucibles are taken out and the metal poured into moulds. At Holywell, out of the six crucibles used to one furnace, the quantity of brass obtained is about as much as would fill one of them. This makes in subsequent manufacture a single large plate, which is manufactured in the same way as copper plate. Or, more accurately, from forty pounds of copper and sixty pounds of calamine, about sixty pounds of brass are obtained, besides the loss of a good deal of zinc by the unavoidable escape of much of it in form of vapour through the pores of the lute or the crucible-covers.

The above is the usual process of brass-making in this country, and is essentially the same wherever this alloy is manufactured, but with some variation as to the choice of ingredients, their proportions, the time of fusion, the shape of the furnace and other smaller circumstances.

At Goslar, in Saxony, where brass is largely made, the zinc is furnished not by a native calamine but the *cadmia* or sublimed oxyd of zinc, which is collected for this purpose in a particular part of the chimnies of the reverberatory

furnaces in which the Saxon lead ores and blendes are roasted.

A great variety obtains in the respective proportions of the ingredients. According to Swedenborg^b they are, in Goslar, 30 parts of copper, 40 to 45 of *cadmia*, and twice the volume of charcoal; at Paris, and in many of the French manufactories, they are, 35 of copper, 35 of old brass, 40 of calamine, and 20 to 25 of charcoal; in Sweden, 30 of copper, 20 to 30 of old brass, and 46 of calamine, with charcoal sufficient; or, 40 of copper, 30 of old brass, and 60 of calamine; and in England, generally about 40 of copper and 60 of calamine. The product of brass varies also, but it seems to be in few places so great as in some of the English works, where, as already mentioned, 40 pounds of copper become in the process 60 pounds of brass. This superior quantity is ascribed partly to the goodness of the calamine and partly to the smallness to which the copper is previously reduced by being poured melted into cold water, and thus affording a great surface of metal to the action of the zinc vapour.

At Stolberg,^c near Aix-la-Chapelle, where brass is very largely manufactured, the furnaces are cylindrical, and each contains eight crucibles arranged in two tiers of four each. These crucibles are fifteen inches high, twelve inches deep, and eight or nine inches wide. The proportions of ingredients are 40 lb. of copper, 65 lb. of calamine, and double its volume of charcoal. After the fire has been kept up for twelve hours, the crucibles are uncovered, and a workman takes off with an iron trowel all the scum and charcoal which swim upon the liquid metal, and which is called *arkeft*. When examined with a glass, this is found to consist of calamine and copper particles, cohering together but not completely united. The brass resulting from this first process is coarse, brittle, and unequal in texture, and requires a second fusion before it is fit for use. For this purpose the same crucibles are again employed and are filled, first with three handfuls of the mixture of calamine and charcoal, over which are put two or three pounds of the impure brass broken in pieces, then more calamine and charcoal, with a lump of the *arkeft*, and over all, calamine and charcoal powder. The crucible is then strongly heated for two hours, after which the brass is fit to be cast into plates, which is done here in the following manner. A mould is formed of two blocks of granite, five feet long, three and

^a Macquer's Dictionary.

^b Repertory, vol. xiv.

a half broad, and eight inches thick. They are placed one above the other, the upper one being only moveable, and furnished with a tackle and pulleys for that purpose, and before casting, the surface is smeared with cow-dung. To give the plate the requisite thickness, hoops of iron of different dimensions are adapted to the under stone, so as to confine a determinate quantity of melted metal. The stones are then gently inclined and the melted brass let in between them. These plates are afterwards laminated: some of them are cut into slips by strong shears, for the further purpose of being drawn into wire, and otherwise manufactured in various ways.

A single process, where the fire is kept up long enough and the materials are good, is certainly sufficient to make good malleable brass, but it is probable that the excellence and beauty of the article are improved by making it undergo a second cementation with fresh calamine and charcoal.

In the laboratory brass may be made very well in the small way in a much shorter time.^d Put into a crucible a mixture of calamine and charcoal, bury it in the requisite proportion of copper shot, cover the whole with charcoal powder, lute on a cover to the crucible, and heat slowly in a wind-furnace for half an hour, till the zinc begins to burn off in a blue flame round the top of the crucible, then raise the fire and heat briskly for half an hour longer.

This process of cementation is also neatly shewn by the following management, as given by Cramer.^e Put the mixture of calamine and charcoal into a crucible, cover it with a thin layer of clay, over which when dry lay a thin plate of copper, cover the whole with fine charcoal powder, and lute on a cover to the crucible. Apply heat gradually, and the vapour of the reduced zinc will rise through the floor of clay, penetrate the red-hot copper plate above it, and gradually convert it into brass, which at the end of the operation will be found lying melted on the stratum of clay. The increase of weight gained by the copper in this operation will afford a good practical test of the goodness of the calamine, and its fitness for brass-making in the great way.

The most important properties of brass compared with copper are the following: the colour of brass is much brighter, and more approaching to that of gold; it is more fusible than copper; less subject to rust and to be acted on by the vast variety of substances which corrode copper with so much ease; and it is

equally malleable when cold, and more extensible than either copper or iron, and hence is well fitted for fine wire. Brass however is only malleable when cold. Hammering is found to give a magnetic property to brass, perhaps however only arising from the minute particles of iron beaten off the hammer during the process and forced into the surface of the brass, but this circumstance makes it necessary to employ unhammered brass for compass-boxes and similar apparatus.

The expansion of brass has been very accurately determined, as this metal is most commonly used for mathematical and astronomical instruments, where the utmost precision is required. Mr. Smeaton found that 12 inches in length of cast brass, at 32°, expanded by 180 degrees of heat (or the interval from freezing to boiling water) 225 ten thousandth parts of an inch. Brass wire under the same circumstances expanded 232 parts; an alloy of 16 of brass with 1 of tin expanded 229 parts. The expansion of hammered copper is only 204 such parts, but that of zinc is 253, so that brass holds a middle place in this respect between its two component metals.

Most of the zinc readily burns off from brass when kept melted in a strong heat with free access of air. When the heat is equal to that of melted copper, the zinc takes fire and slowly burns away. At last little else but copper remains, but still united with a small portion of zinc, which no further continuance of the fire will entirely separate.

Some kinds of very fine brass are said not to be made by cementation in the way already described, but by a more speedy and direct union of copper and zinc, care being taken to prevent the access of air to the materials while in fusion. Very fine brass may also be made by mixing together the oxyds of copper and zinc, and reducing them with a carbonaceous flux. This idea is ingenious, and from the intimate mixture of the two metals which it promises, it deserves to be further pursued. Sage gives the following experiment to this purpose.^f Mix together 50 grains of the oxyd of copper, remaining after the distillation of verdigris (which is very pure) with 100 grains of lapis calminaris, 400 grains of black flux, and 30 grains of charcoal powder; melt the mixture in a crucible till the blue flame is seen no longer round the lid of the crucible, and when cold a fine button of brass is found beneath the scoria, weighing a sixth more than the copper.

^d Sage.^e Ars docimaft.^f Journ. de Phys. vol. xxxviii.

alone, obtainable from its oxyd in the same way but without the calamine. This brass has a very fine colour like gold.

On this experiment M. Sage observes that there appears to be a point of mutual saturation between the two metals, which is when the copper retains one-sixth of zinc, and this portion it will retain however long it is heated, provided the surface of the melted metal be covered to protect the zinc from the action of the air; but if the brass contains a greater proportion of zinc, precisely this excess will escape, even in covered vessels, and will burn when it comes out to the air. The same chemist also observes that the colour is the finest at the above proportion. These experiments seem to require further confirmation, but at present we may reckon that to be the most perfect brass which is composed of about 14.28 per cent. of zinc and 85.72 of copper, and which is not liable to any alteration in its constituent parts by successive or long continued fusions, provided the access of air be prevented.

The analysis of brass has been attempted in various ways, and several processes have been given of different merit.

Brass may be to a certain degree analysed by simply being kept in fusion at a high heat with free access of air. The zinc readily burns, and by far the greater part of it escapes, and when the blue flame of the metal ceases the analysis is supposed to be complete, the loss of weight on the remaining metal indicating the quantity of zinc. But this is inaccurate from two causes; first, that a portion of zinc always remains in the copper however long the heat be continued, and secondly that part of the copper oxidates in the process, and thereby gains an increase of weight. Both these circumstances therefore contribute to indicate a smaller proportion of zinc than is really the case.

A simple solution of brass in the sulphuric acid and subsequent crystallization has also been recommended, on the idea that the crystals of sulphat of zinc could readily be obtained separate from those of the sulphat of copper. But though this separation takes place to a considerable degree it is not complete, for at the last the crystals of each salt are somewhat alloyed with the other, and the trouble of picking out the crystals when very small is extreme.

M. Dizé^{*} proposes the following methods.

1. Dissolve the brass in nitric acid, which takes up the copper and zinc and leaves any tin with which it is often alloyed. Decompose the clear

nitrated solution by potash, redissolve the precipitate in sulphuric acid, and add a piece of clean bright iron to the solution, previously diluted with six times as much water. The copper is by this means precipitated in a metallic state, and the solution now holds sulphat of iron and sulphat of zinc. Add gallic acid, which will slowly separate the iron and leave the zinc. Lastly, decompose the sulphat of zinc by a carbonated alkali, and estimate the quantity of zinc contained in the carbonated oxyd of zinc thus obtained, by proportions which will be presently mentioned. The above method is useful, but the separation of the iron by the acid of galls is excessively tedious.

2. Dissolve the brass in nitric acid. Dilute with six parts of water, and immerse in the solution a cylinder of bright clean lead. The copper speedily separates in the metallic form round the lead, which last takes its place in the solution. As this process advances the liquor loses its blue colour, and when all the copper is separated it is slightly yellow. To be certain that no copper remains in the solution, add a fresh clean piece of lead and boil for some time. The liquor now contains nitrat of lead and nitrat of zinc. Sulphuric acid will now precipitate the lead in the form of an insoluble sulphat, and the nitrated zinc may then be decomposed by a carbonated alkali.

On this precipitation however there are several things to be observed. Copper, as Vauquelin remarks,^h when dissolving in nitric acid absorbs nearly $\frac{4}{100}$ of its weight of oxygen, but lead under the same circumstance absorbs only $\frac{1}{100}$. Hence 100 parts of copper dissolved in nitric acid would require for their disoxygenation (a process which takes place whenever a metallic oxyd in solution is precipitated by the immersion of another metal in its metallic state) full 250 parts of lead, which last is of course oxydated in proportion as the copper is precipitated in the metallic form. But this large quantity of oxyd of lead cannot be held in solution by the nitric acid, except this is largely in excess, and this explains the reason of the appearance of a portion of oxyd of lead (as M. Dizé has observed) which forms at the latter end of the process and mixes with the newly precipitated metallic copper, so as to require a subsequent operation to separate them. Nor will an excess of nitric acid ensure the purity of the precipitated copper, for it happens here, as is now found to take place in very many of the reguline metallic precipitates, that the newly-separated

^{*} Jour. de Phys. tom. 48.

^h An. Chim. tom. 28.

metal is not pure, but largely alloyed with the metal added as a precipitant. Therefore the loose flocculent metal which forms around the piece of lead is not pure copper, though it has a perfect cupreous appearance, but is copper largely alloyed with lead. Vauquelin found that if 50 grains of pure copper are dissolved in an excess of nitric acid, and then entirely precipitated by metallic lead, of which about 220 grains are required, the cupreous precipitate now weighs 138 grains instead of the original 50, and therefore is not pure copper but an alloy of 50 parts of copper with 88 parts of lead. This method therefore of analysing brass cannot be depended on, unless the cupreous precipitate be afterwards separately treated to separate the lead, which would render the analysis very complicated.

The following methods are given by Vauquelin.

3. Dissolve a known weight of brass in nitric acid; put it into a well closed bottle and add caustic potash to excess, so that there shall be a very sensible alkaline taste in the liquor, shake the mixture well, and keep it some time in digestion. By this process the oxyds of copper and zinc are first both precipitated by the alkali, and afterwards the zinc alone redissolved in the excess of potash, so that the clear solution is oxyd of zinc in potash, and the sediment left undissolved is the oxyd of copper. This oxyd is brown and nearly of the colour of metallic copper, but when thoroughly washed and gently dried, it only contains 65 per cent. of the metal. If a previous assay has shewn that the specimen of brass contained only copper and zinc, when the weight of the former is known, that of the other may readily be inferred; or else, the alkaline solution of zinc may be supersaturated with sulphuric acid, so as first to precipitate and afterwards to redissolve the metal, when the sulphuric solution may be decomposed by a carbonated alkali. A very trifling quantity of copper passes into the alkaline solution of zinc, occasioned by the action of a small quantity of ammonia, generated by the nitrated metals when caustic alkali is added to them. If necessary this might be again separated by a heat cautiously kept below boiling, which would expel the ammonia, the cause of this error, but if brought fully to boil some of the zinc would separate from the alkali and cause a much greater error than before.

4. Dissolve brass in sulphuric acid, dilute with twenty times as much water, and immerse a stick of zinc exactly weighed. The copper

soon completely precipitates in the metallic form, and requires only to be well washed and weighed. The solution now contains only the zinc of the brass, together with the zinc lost from the piece immersed to precipitate the copper. By weighing the remainder of the stick of zinc, and precipitating the whole by carbonated potash or soda, an easy calculation will determine how much of the oxyd of zinc is derived from the zinc contained at first in the brass. Or, more simply, this may be inferred from the copper obtained, and the quantity of brass originally employed.

It remains on the subject of analysis to give the constituent parts of carbonat of zinc. M. Dizé dissolved 100 parts of zinc in nitric acid, precipitated it by carbonated soda, and this product well washed and dried now weighed 180 parts. Hence 100 parts of carbonat of zinc thus prepared would indicate 55.5 of metallic zinc.

On the other hand Vauquelin found that carbonat of zinc obtained from the sulphat by carbonated potash, well washed, and calcined in a crucible to expel all the carbonic acid, contained 69 per cent. of metallic zinc. Hence the carbonat obtained by Dizé must have been dried at a low temperature, probably that of boiling water, and from either of the above data the proportion of zinc may be estimated; or else the carbonated oxyd may be mixed with about a fourth of charcoal and strongly heated in an earthen retort with the beak dipping in water, by which the zinc will be reduced and will rise into the neck of the retort, or partly fall into the water beyond.

Analysis shews a vast variety in the proportions of the different species of brass used in commerce. In general the extremes of the highest and lowest proportions of zinc are from 12 to 25 per cent. of the brass. Even with so much as 25 per cent. of zinc, brass, if well manufactured, is perfectly malleable, though zinc itself scarcely yields to the hammer. M. Dizé analyzed a specimen of remarkably fine brass made at Geneva, for the purpose of escapement wheels and the nicer parts of watch-making, the perfect bars of which bear a very high price. This metal unites great beauty of colour to a very superior degree of ductility. It was found to consist of 75 of copper with 25 of zinc, and probably too the copper was Swedish or some of the finer sorts. The common brass of Paris seems to contain about 13 per cent. of zinc, the English probably more.

The uses of brass are too numerous to be

mentioned. It is applicable to an infinite variety of purposes, is easily wrought by casting and hammering, and by the lathe, its wire is eminently useful, and it takes a high and very beautiful polish. The appearance of brass is given to other metals by washing them with a yellow lacquer or VARNISH, a substitution often very much to the detriment of the manufactured article.

Many other yellow alloys of copper are used, such as bronze, bell-metal, &c. most of which are triple compounds, and will be noticed under the article COPPER.

BRAUNSPATH. *Pearl-spar. Sidero-calcite* of Kirwan. *Spath brunissant* of Brochant. *Chaux carbonatée ferrifère* Haüy.

The colour of this mineral is milk-white, passing into greyish, yellowish or reddish-white; or rose-red passing into flesh, blood, or brownish-red: when it has been exposed for some time to the action of the weather it becomes first of a yellowish grey colour, and then verges into ochre or Isabella-yellow, yellowish, reddish, liver and blackish-brown. It is sometimes spotted, an accident that happens most frequently with the red-coloured varieties.

It occurs generally crystallized, and the forms of its crystals that are determinable are the same as certain varieties of calcareous spar. Its primitive figure is a rhomboid exactly corresponding with that of calcareous spar. The other figures are,

1. Equiaxe (of Haüy); a very obtuse rhomboid.
2. Inverse (of Haüy); an acute rhomboid, which is the primitive figure inverted.
3. Contrastante (of Haüy); a still more acute rhomboid than the preceding.
4. Basée (of Haüy); the primitive rhomboid, the two summits of which are intercepted by two triangular facets.
5. Dihexaèdre (of Haüy); an oblique six-sided pyramid, the alternate angles of which are equal.

The undeterminable forms of this mineral are,

6. Lenticular (*lenticulaire* of Haüy); which differs from the *équiaxe* in having the faces and angles rounded.
7. Curvilinear rhomboid (*contournée* of Haüy); a small rhomboid, all the faces of which form a fold in the direction of their oblique diagonal.

It also occurs in minute interlaced rhomboidal scales, some of which have a considerable resem-

blance to blende; or in globular masses or cellular.

The surface of the crystals is generally drusy, except of the rhombs, which are smooth. Its external lustre is more or less shining, with a pearly lustre, but when in a state of commencing decomposition it has usually a variegated semi-metallic appearance. The fracture of braunspath is strait or curved-foliated, exhibiting a threefold obliquely intersecting cleavage, like calcareous spar. It flies when broken into rhomboidal fragments. It is translucent on the edges, rarely entirely translucent. Its hardness is a little superior to that of calcareous-spar. Sp. gr. 2.83, according to Brissou; the Isabella yellow variety, according to Kirwan = 2.39.

Before the blowpipe braunspath crackles and falls to pieces, and becomes of a brownish black colour (hence its name) but does not melt: with borax it runs into a frothy slag. By exposure to a long continued high heat in a charcoal crucible, it becomes a dark brown friable mass, studded with minute metallic grains; in a clay crucible it produces a brown glass, translucent on the edges and transparent in thin shivers.^b It effervesces with acids, though feebly, and not except it is pulverized.

The massive variety, when calcined and mixed with sand forms a strong and valuable cement, which sets quickly and is impenetrable by water.

The constituent parts of braunspath, according to Bergman, are

50	carbonat of lime,
22	oxyd of iron,
28	oxyd of manganese.

100

But a specimen that was analysed by Berthollet, at the desire of Haüy, contained only about 4 per cent. iron and manganese, the rest being carbonat of lime. On this account, and because its crystallographical characters agree with those of calcareous spar, M. Haüy combines the white or spathose iron ore with braunspath under the name *Chaux carbonatée ferrifère*, and ranks it as a family of calcareous spar.

Many of the calcareous spars which are esteemed pure, appear when analysed by nitrous acid to contain iron; and perhaps a regular progression may exist from calcareous spar with the smallest quantity of iron, to braunspath, and finally to spathose iron ore, or carbonat of iron with the smallest quantity of calcareous spar. This however is as yet by no means ascertained,

^a Emmerling, Kirwan, Haüy, Brochant, Jamefon,

^b Klaproth. *Analyt. Ess.* i. p. 10.

and it is on many accounts more convenient to arrange the spathose iron among the ores of this metal, and to make distinct species of braunspath and calcareous spar.

It occurs chiefly in veins accompanied by calcareous spar, spathose iron ore, galena, blende, pyrites, yellow copper, and various ores of silver. It is found in the mines of Norway, Germany, Sweden, France, Hungary, and England. At Ormes head, in Caernarvonshire, it is found in veins with copper and manganese, and also very abundantly in mass.

BRAZIL WOOD or *Fernambouc Wood*. *Sapan Wood*. The tree which bears this wood is the *Cæsalpina Crista*, Linn. The wood is very hard, takes a high polish, and is so heavy as to sink in water. When chewed it gives a sweetish taste. It much resembles in appearance Red Saunders wood, but differs from it essentially in readily giving out its colour to water, which Saunders wood does not.

Brazil wood is valuable for the beautiful orange and red colours, in various shades, which it furnishes to the dyer, but the colour is naturally very fugitive, though it may be to a certain degree fixed by various mordants.

When raspings of brazil wood are boiled for some time in water they give a fine red decoction. The residue appears black, but alkalies will continue to extract a colour from it after the action of water is exhausted. Spirit of wine and ammonia also extract a colour with great facility, which is somewhat deeper than the watery decoction.

When sulphuric acid is added very gradually to a fresh watery decoction of Brazil wood, a small quantity of red precipitate falls down, and the clear liquor now becomes yellow. Nitric acid produces a similar change, but the liquor is more of an orange. Most of the other acids also agree with the former in producing a red precipitate, and leaving the clear liquor of different shades of yellow or orange. The alkalies added to this liquor restore the original red colour, but with a cast of crimson or violet.

Brazil wood decoction, or infusion in water, is readily turned of a violet or purple blue by alkalies, and this change is produced by so very minute a quantity as to furnish a chemical test of the presence of alkalies, of very great utility. According to Bergman,^b in his valuable analyses of mineral waters, 10 grains of crystallized carbonate of soda, which contains no more than about 2.15 grains of mere alkali, dissolved in a Swedish kanne (5.5 English pints) of water, give

a sensible purple tinge to paper reddened by Brazil wood. There is however some ambiguity in this test, as the same change is produced by a solution of lime or magnesia in carbonic acid and water, a very frequent occurrence in most natural waters. Evaporating the water for some time will distinguish whether the change on Brazil wood is produced by an alkali or a carbonated earth; for, if by the former, the purple will be more intense in the concentrated water, as it now holds a greater proportion of alkali; but if by a carbonated earth, the effect will be lost, as the boiling expels the loose carbonic acid, and precipitates the carbonated earth which it held in solution.^c

The effects of the solutions of tin and alum on Brazil wood are the most important to the dyer. Alum added to the watery decoction of the wood gives a copious fine red precipitate, inclining to crimson and subsiding slowly. The supernatant liquor also retains the original red colour of the decoction, but if enough of alkali is added to decompose the alum, its earth falls down and carries with it nearly all the remaining colouring matter of the wood. In this way a fine crimson LAKE, imitating the cochineal carmine, may be prepared, which therefore consists of alumine, intimately combined with the colouring matter of the wood a little heightened.

Nitro-muriat of tin added to the decoction separates the whole of the colouring matter, which falls down in great abundance in union with the oxyd of tin, and the liquor remains colourless. Even when the original colour of the wood has been previously altered by acids, the tin solution first restores the natural colour, and then precipitates the colouring matter as with the fresh decoction.

The solutions of iron blacken the decoction or infusion of Brazil wood, shewing the presence of the gallic acid.

Many of the other metallic solutions act similarly to that of tin, in forming lakes, consisting of the colouring matter of the wood united with the metallic oxyd of the solution employed.

The colour of Brazil wood, though highly beautiful is readily fugitive, and has the additional disadvantage of being darkened and rendered purple by soap, which therefore cannot be employed in washing cloth dyed with this colour. Acids render the colour permanent, but change it yellow. It is peculiarly distinguished from the colouring matter of kermes and madder, by having the original crimson-red restored by solutions of tin, after having been

^a Berthollet.

^b Essays.

^c Kirwan on Min. Waters.

altered by acids. Accordingly the best practical dyers have employed acids and tin in their attempts to fix this beautiful colour. (See the article DYEING.)

BREAD. *Pain*, Fr. *Brot*, Germ.

Bread is a light porous spongy substance, prepared by fermentation and baking from the flour of certain farinaceous seeds, especially wheat, and is the principal sustenance of man in the temperate regions of the Northern hemisphere.

It is not likely that the unprepared grains of wheat were ever the habitual food of man; for by mastication the gluten that they contain coalesces into a tough elastic mass, equally unpalatable and indigestible. We read however of corn being fitted for use on sudden emergencies merely by parching, and this was probably the simplest and earliest method of converting it into human food. The next advance was to pulverize the grains in a mortar or hand mill, to separate the coarse bran from the finer particles, and by the addition of water or milk to form these latter into a tough paste, which being rolled into flat thin cakes was rendered eatable by toasting on a hot stone or plate of metal. The Romans in the early period of their republic, and also the Carthaginians, appear, like the modern Italians, to have consumed their corn principally in the state of polenta or furmety, in which the wheat undergoes no further preparation than being boiled till the grains are swollen considerably and are become tender. By all these methods the most pressing objection to the use of wheat, namely, its forming a tough glutinous mass during mastication, was completely got rid of, the action of fire alone, or of fire combined with water, producing the necessary change in the gluten with which this species of corn abounds. Still however it was destitute of that peculiar lightness and flavour which it acquires when converted into bread, properly speaking, by a slight degree of fermentation.

The flour of wheat is composed of fecula or starch, and a gluten exactly resembling in its properties and composition the gluten of blood, together with a small proportion of saccharine mucilage. When kept dry, and at a temperature not exceeding that of boiling water, it appears incapable of undergoing any spontaneous change, and continues in the state of a fine impalpable powder, but if mingled gradually with a sufficient quantity of water to form a thin tenacious paste, and exposed for a day or two to a warm air, the process of spontaneous decomposition begins to shew itself. The colour of the mass becomes yellow, the flat sub-nau-

feous smell becomes acidulous and sensibly pungent, and the bulk is somewhat increased, owing to the disengagement of small bubbles of carbonic acid gas: these signs of fermentation presently become more and more apparent, and the paste passes rapidly into the putrefactive state, exhibiting the usual signs of this species of decomposition, modified however by the acetous fermentation which takes place at the same time.

This change appears to be certainly begun and principally carried on by the gluten; although the *panary fermentation*, as it has been called, is supposed by many chemists to be produced by the contemporaneous action of three distinct fermentations, to which the three elements of wheaten flour are respectively subject. They imagine the vinous fermentation to take place in the saccharine mucilage, the acetous in the starch, and the putrefactive in the gluten at the same time, and from the modification of each by the others, they consider that peculiar action to originate which converts paste into bread. Against this opinion however the following objections may be urged. In the first place, the quantity of saccharine mucilage is so extremely small as to produce no sensible effect on the whole mass, and what little there is probably passes immediately into the acetous fermentation. Secondly, the temperature that is required for bread-making is considerably lower than that at which starch dissolves in water, and where this is the case no alteration will take place, even in a long course of time: this is clearly shown by the usual process of starch-making, in which the bruised wheat is fermented for several days in large vats, in order to destroy the gluten, after which the starch is procured by simple deposition from the washings of the residue. So essential is the presence of gluten to the preparation of bread, that its perfection is almost exactly in proportion to the quantity which it contains of this ingredient. Hence wheat yields the best bread, because it is composed of a larger proportion of gluten than any other grain, and hence rice, millet and oats are incapable of being converted into bread because they contain little or none of it. In further confirmation of this it may be remarked that if the gluten of wheat (procured by simple washing as described under the article GLUTEN) be incorporated by careful kneading with rice-flour, a fermentable cohesive paste is thus produced, from which perfect bread may be made in the usual manner. It would be a curious enquiry, and one of no small importance to the

inhabitants of the northern parts of Europe, to ascertain how far the simple farinaceous seeds, and the oily farinaceous ones after expression of their oil, are convertible into bread by mixture with the gluten of blood.

If wheaten dough is kept till fermentation is completely established in it, as will be evident from its yellow colour and its aced smell and taste, it will be converted into *leaven*; and this leaven, if incorporated with fresh dough, will bring the whole into a fermenting state, much more speedily and uniformly than if the mass was exposed to spontaneous decomposition.

The discovery of the advantages of mixing old dough with new appears to have been made very early, and the distinction between leavened and unleavened bread is noticed even in the most ancient historical records. Ancient Greece received from Egypt the important art of making bread, and transmitted it to Rome, whence it extended by degrees over the whole of Europe. But though leavened bread is perfect in every other respect, it always retains a slightly acidulous flavour from the leaven by which it is fermented, for it is impossible to carry the fermentation of the gluten to a sufficient extent to change it into leaven, without at the same time exciting the acid fermentation in the sugar of the flour. It was therefore a very important improvement in the art, and one which we believe is attributable to the English bakers, to substitute yeast or the froth of malt-liquor in a state of fermentation, to leaven; for the former not only communicates no unpleasant flavour to bread, but is also a more speedy ferment, and by acting first on the gluten of the flour produces the desired effect before any acid has time to be evolved from the other ingredients.

The process of making common bread is extremely simple, though its perfect success depends considerably on a kind of knack in manipulation, which cannot be described by words. It is of essential consequence that the flour and yeast should be mixed together with perfect accuracy, in order that the whole mass may be equally fermented, and that this action may commence in every part at the same time. Now though in the making of a single loaf this may easily be effected at one continued process, yet where a considerable quantity of bread is to be made at once, this is impracticable.

The bakers of Paris have the reputation of being remarkably skilful in their business, we shall therefore have recourse to the Encyclo-

pedie* for an account of the most approved practice of this important art.

The ingredients of the best bread are wheaten flour, water, yeast, and salt. 150 lbs. of flour require about 85 pints of water, 3 pints of yeast, and a proportion of salt, which varies considerably according to the fancy of the baker and the degree of dryness which is to be given to the bread in the oven. The manufacture commences by diluting the yeast with about an equal quantity of warm water, and then stirring in one pound of flour for every pint of liquid; the whole being well incorporated it is put into a wooden bowl and set in a warm place for about seven hours, in order to ferment. At the end of this period the mass (our English bakers call it the *sponge*) is put into a large wooden trough and mixed with one-seventh of the whole quantity of flour, the whole of the salt, and with water in the proportion of one pint to two pounds of flour. The dough is now brought into a warm situation, and allowed to remain quiet for four hours that the fermentation may be established throughout the whole: the salt somewhat retards the progress of this action, but at the same time has the advantage of rendering it more gentle and uniform. The next step is to mingle two-sevenths of the flour and three-fourths of its weight of water with the dough in the same manner as before, after which it is to be allowed two hours to ferment. Now commences the kneading and hard manual labour of the process, during which the remaining four-sevenths of the flour, and half as many pints of water as there are pounds of flour are to be thoroughly mingled with the fermented dough: at first the mass is very adhesive and clings to the fingers, but it becomes less so the longer the kneading is continued; and when the fist on being withdrawn leaves its perfect impression in the dough, none of it adhering to the fingers, this laborious part of the business is completed. The dough is now immediately divided by weight into loaf-pieces, each of which is once more separately kneaded, and then made up into the proper form. The loaves as they are made are placed on a wooden table, and piled on each other two tiers high, and covered with a blanket to promote the last rising or fermentation, which soon commences, and is judged to have proceeded sufficiently far when a penetrating somewhat acidulous odour of carbonic acid is perceived. The oven is in the mean time heated, and when the tempera-

* Arts. & Metiers. art. Boulanger.

ture is such that a little flour spread at its mouth is browned but not burnt, the loaves are deposited within, the mouth is closed up with an iron door, and at the proper time (varying according to the size of the loaves) the bread is withdrawn, is replaced on the table and again covered with a blanket, in order to cool as slowly as possible; the ashes and adhering flour are then removed with a brush and the bread is ready for sale.

The changes produced upon dough by baking are very remarkable, nor can they in any degree be attributed to evaporation, since the loss of weight never ought to exceed $\frac{1}{30}$, and is very often not greater than $\frac{1}{60}$. In the first place the progress of fermentation is entirely stopped: the bread may be kept for several days without experiencing any alteration, and the first sign of spontaneous change is its becoming mouldy. Secondly, the tenacious ductility of the dough and its compact texture, are exchanged for a moderately firm and slightly elastic consistence, and a very spongy texture, in consequence of the alterations produced in the gluten by heat and moisture. Thirdly, the fecula or starch which was merely diffused through the dough without being in any degree affected by the *panary fermentation*, is combined during the baking with a portion of water into a stiff gelly, like common starch when boiled with water, and thus renders the bread considerably more transparent than dough, as well as more digestible.

Rye and barley are the only substances besides wheat that are capable of being made into bread, because they alone contain gluten enough to admit of being formed into a moderately tenacious paste with water. Even in these however, the proportion of gluten is too small to afford light bread without the use of an acid ferment to disengage the proper quantity of carbonic acid; so that they can never for the purpose of the baker be at all comparable to wheaten flour.

BRECCIA. *Breche*, Fr.

This term was first we believe employed by the Italian statuary to denote those kinds of marble which are really or apparently composed of angular fragments of marble cemented together by a posterior infiltration of calcareous spar or marble. Some of the French mineralogists have adopted the term and extended its meaning, so as to include any stony mass composed of angular fragments consolidated by a cement. Hence they subdivide the generic term *brèche* into calcareous, magnesian, siliceous,

and argillaceous, and discriminate it from amygdaloid or poudingue (from the English pudding-stone) by restricting the meaning of this latter to stony masses formed of rounded pebbles imbedded in a cement. Neither this term nor any analogous to it is admitted into the nomenclature of the German mineralogists.

BRIMSTONE. See SULPHUR.

BRONZE. See COPPER alloys of.

BRUNSWICK-GREEN. *Braunschweigische grun*, Germ.

This is a pigment used by some of the German artists, and is prepared as follows. Take one part of muriated ammonia and make a saturated solution of it in cold water, put it into a tumbler, or any other convenient glass vessel, and add to it three parts of copper clippings; cover the mouth of the vessel with a piece of gauze to keep out the dust, and place it in a warm situation, so that in a few days the moisture will be evaporated. The muriat of ammonia presently begins to be decomposed by the copper, which in its turn is corroded and converted to a green oxyd. When the whole is evaporated to dryness, digest it in two or three successive portions of spirit of wine, as long as any green oxyd is taken up, add the solutions together and drive off the liquor by a gentle heat; the residue is a pure dark-green sub-muriat of copper, known in the shops by the name of refined Brunswick-green.

BUTTER. See MILK.

BUTTERS MINERAL. A name given by the old chemists to some of the sublimed metallic muriats, on account of their soft butyraceous texture when recently prepared. There are four metals which afford mineral butters, viz. Antimony, arsenic, bismuth, and tin, and the peculiar properties of each of these salts are mentioned under the respective metals. The circumstances in which they all agree are the following. They are formed by sublimation; their consistence is like that of common butter in warm weather, and a gentle heat resolves them into a dense oily-looking liquor; they are decomposable by being dropped into pure water, a copious precipitation of white oxyd taking place. When the French nomenclature was newly introduced they were called oxymuriats: but it appears from later experiments that the excess of oxygen which they contain over the common muriats, is combined not with the acid but with the metal.

BUTTERS VEGETABLE. Such of the vegetable expressed oils as require a greater heat

than that of the atmosphere to preserve them in a fluid state have obtained the name of *vegetable butters*. Of these the best known to Europeans is the *Palm OIL*, procured from the fruit of the *Cocos butyracea*. The common Cocoa-nut also, and the Chocolate-nut, may be made by pressure to yield a similar concrete oil. Mr. Park, in his travels in Africa, describes another tree, called by the natives Shea, from the fruit of which a

very pure butter is also obtained. See *OILS VEGETABLE expressed*.

BUTTON. *Korn*, Germ. *Bouton*, Fr.

The rounded mass of metal which is collected at the bottom of a crucible after fusion, or which remains in the cupel after cupellation, is called by this name. If the button is solid, slightly convex and smooth on its upper surface, it is a sign of the process of reduction or cupellation having been well performed.

C

CACHOLONG. See *CHALCEDONY*.

CALAMINE. See *ZINC*.

CALCAREOUS EARTH. See *LIME*.

CALCAREOUS SPAR. See *LIMESTONE*.

CALCINATION. *Calcination*, Fr. *Calciniren* *Verkalchen*, Germ.

CALX. *Chaux*, Fr. *Kalk*, Germ.

The term calcination is derived from the latin *calx*, which signifies quick-lime, and is applied by the old chemists to the conversion of a comparatively dense substance into a light and porous one, by the action of fire. The diminished specific gravity of bodies that have undergone calcination was supposed in all cases to prove the volatilization of one or more of their constituent parts, and as this was in many instances accompanied by combustion, the two terms came in some measure to be confounded. Hence in the writings of Glauber, Kunkel, and even Bergman, we find *ustus* used almost synonymously with *calcinatus*. There is however this distinction to be noticed between them, that *ustus* refers simply to the process, while *calcinatus* respects also the result of the process. Thus *ustion* may be performed repeatedly on the same substance, producing more or less change in it each time, but calcination when once brought about is perfect, and a pure calx is liable, by any subsequent exposure to heat, only to be vitrified. For example: if a bone is placed in an open fire, the oil soon begins to exude and burns with a bright flame; when this ceases the residue is, properly speaking, *burnt bone*, and consists of earthy matter penetrated by charcoal; by a second exposure to fire the burnt bone loses its charcoal, and nothing remains but the white earth; it is now in the state of *calcined bone* or *bone-ash*, because it is incapable of any further decomposition by simple heat. A calx therefore is to a substance burnt in an open fire, what a *caput mortuum* is to a substance that has been distilled; they are each the ultimate results

of the action of heat in open and in close vessels. Most metals when exposed to the joint action of heat and air are converted to a loose powdery substance which was denominated by the old chemists the calx of the metal, but which in the modern nomenclature is called an oxyd: and because the action of acids, especially the nitric, has a similar effect on some of the metals to that which is produced by fire, the term calcination when applied to these bodies indicated the conversion of them into calces either in the moist or dry way. But though the old term, as applied to metals, is superseded by oxidation, yet it may still very conveniently be retained to express the separation of the fixed from the volatile parts of bodies by means of a naked fire. In which sense we say calcined bones, calcined flints, calcined potash, calcined clay, &c.

CALCINED MERCURY. *Mercurius calcinatus*. A common pharmaceutical name for the simple red oxyd of mercury. See *MERCURY oxyds of*.

CALCULUS biliary. See *BILIARY CALCULUS*.

CALCULUS urinary. See *URINE*.

CALOMEL. See *MERCURY*.

CALORIC or *Heat*. *Calorique*, Fr. *Wärmestoff*, Germ.

The nature and properties of heat afford a most extensive and interesting subject for philosophical enquiry, which has been pursued with so much ardour and success that it would occupy a volume barely to enumerate all the researches to which it has given rise for the course of more than a century in many countries of Europe. We must therefore content ourselves with selecting the results of a few only, and particularly of those of later date, together with a general view of the present state of knowledge on this subject, which the experience of every year shews to be still imperfect, and still to promise a rich harvest of discovery for future enquirers.

The substitution of the term *caloric* to that of *heat*, has in a great measure arisen out of the prevailing idea of the materiality of heat, whence it was thought necessary to guard against a confusion of ideas that might arise from giving the same term to the sensation of warmth in the animal body, and to the cause of that sensation. But though the term *caloric* is well devised, it does not happen in fact that when its nature is understood, any material inconvenience arises from this mixture of terms; and therefore in compliance with common language we shall use indiscriminately the appellations of *heat* or *caloric* to imply that supposed material substance which possesses the power of exciting the feeling of heat in the animal body, together with a vast number of other properties, that render it the most important chemical agent in nature.

The general properties of *caloric* are the following: if material (and the phenomena which it exhibits are on the whole more readily understood by supposing it so) it is a substance of extreme subtlety and tenuity, entirely imponderable by human instruments, derived immediately from the sun together with light, and, like light, obeying certain and similar laws of reflection and refraction, and also elicited by combustion, by friction, and some other sources: when uncombined, moving with immense velocity in every direction, and constantly tending to an equilibrium, penetrating all bodies in nature with more or less facility, and thereby enlarging their dimensions without encreasing their absolute weight: when combined, probably entering into chemical union with other bodies, and thereby constituting the different states of liquid, vapour, or gas: and lastly, when applied suddenly to the animal body occasioning the sensations of warmth, heat, or in greater intensity, burning.

The simplest state of *caloric* that we are acquainted with takes place when a heated body is placed in air, or any elastic medium much colder than itself. The great source of heat, the sun, is probably in this situation, as likewise are all heated bodies, whether in combustion or not, simply exposed to the atmosphere. Thus situated, it is found that sensible heat is constantly radiating from them in every direction with immense velocity, and with an intensity regulated by the nature of the heated surface, and its proportional excess of heat over the surrounding medium.

Again, when a body has been long enough exposed to the radiations of heat to have itself received thereby an excess of *caloric* above that

of the ambient air, it becomes a secondary radiating source, and immediately begins to send forth rays of *caloric* with apparently equal velocity with the primary source, and precisely obeying similar laws of transmission. Thus a vessel of water standing near a hot fire first receives from it constant rays of heat, the water itself becomes hot, and it then begins to send off its acquired heat through the air to the surrounding objects. Hence the constant tendency to an equilibrium which radiant or sensible heat possesses, so that no heated body can remain an instant in contact with a colder one without losing a portion of its *caloric*; and as the heat-evolving processes are going on with unequal intensity through every part of the material world, an eternal-interchanging motion of *caloric* is every where perpetually kept up, which appears to be a grand agent in all the phenomena of nature.

But on the other hand there are two circumstances which prevent or impede this constant tendency to equilibrium which *caloric* possesses, the one, the extreme retardation which heat experiences in its passage through solids and liquids, and the consequent change in the mode of its propagation; and the other, the intimate and probably chemical union which takes place between part of the *caloric* and the body that receives it. Hence it is proper to have an appropriate term to distinguish the passage of *caloric* through solids and liquids, from that of *radiation*, which expresses its free and instantaneous passage through air or an attenuated medium. If a rod of iron is held with one extremity close to a fire, the heat first radiates instantly to the nearest end of the iron, and enters its substance, after which it passes (not immediately as before but slowly) through the whole length of the rod to the most distant extremity, so that several seconds elapse before the hand holding the further end of the rod will be sensible of the passage of the heat. Now, as we shall presently mention, it is probable that heat radiates with the same velocity as light, that is about 200,000 miles in a second, whence may be conceived the immense retardation of its motion when it takes several seconds to pass through an iron rod of a few inches only. Therefore it is probable that the *caloric* enters into a kind of combination with each particle of iron successively in its passage through, and in this mode of propagation it is said to be *conducted*. This faculty also varies very considerably, according to the nature of the substance heated; thus some metals conduct heat easier than others, these again

with more facility than glass, glass easier than wood, wood easier than charcoal, and the like. So that in treating of the subject of conducted caloric, the *conducting power* of the medium must be taken into consideration. Late experiments have also shewn a peculiarity in the mode in which heat passes through liquids, which might justify in them the term *conveyed*^a rather than *conducted*, but still totally distinct from radiated.

Lastly, there are several cases in which caloric conveyed into a substance, either by being radiated or conducted, totally combines with it, losing thereby the sensible properties which it before possessed when in a free state, not raising the temperature of the body with which it is united, and contributing to form the states of liquidity and vapour. The caloric which ice receives from the surrounding bodies when thawing, enters into this chemical union and converts it into the state of water. The caloric is then termed *combined*, *fixed*, or *latent*, and comparatively in different bodies, *specific-caloric*, and many most important enquiries are connected with this part of the subject.

Therefore in investigating the laws and properties of heat it will be convenient first to fall in with the natural subdivisions of the subject as relating to radiant, conducted, and combined caloric.

OF RADIANT OR TRANSMITTED CALORIC.

The first and most magnificent source of radiant heat is the sun, whose rays are perpetually transmitting a vast supply of light and heat with immense velocity. The connection between light and heat was long a subject of much doubt and difficulty, but a late discovery of Dr. Herschel has established the very important fact of the separate identity of these two bodies in the solar ray. The well-known circumstance that the moon's rays, though condensed by the most powerful lens or mirror, possess no ascertainable heating power, is a proof of the existence of light, separate from heat, but still capable of reflection and refraction by the same laws that regulate the motion of direct solar rays. Dr. Herschel^b in his optical experiments on coloured glasses was led to examine the difference between the coloured rays of the sun, with regard to their heating power. He thereby discovered that the most refracted rays of light, the violet, possess the lowest heating power; and the least refracted, the red, the greatest power, and the mean rays of the prismatic spectrum shewed an intermediate power. Thus, in the red rays the thermometer (by the

average of several experiments) rose $6\frac{1}{2}$ degrees; in the green rays, $3\frac{1}{4}$ degrees; and in the violet, 2 degrees; or in round numbers, the effect of the red rays was to that of the green as 2.25 to 1, and to that of the violet as 3.5 to 1.

Pursuing these experiments, the same philosopher found the range of dispersion of the rays of heat by the prism to differ most essentially from that of light; for on applying thermometers of great sensibility successively in a line, beginning at the violet rays and proceeding along the prismatic spectrum, he found not only that the heat increased by advancing towards the red or least refracted rays, but that the heat was greatest at a small distance beyond the extreme limits of the spectrum, that is, where no rays of light at all fell; and still continuing to advance the thermometer in the same line, the heat then gradually diminished till it became too small to be noticed. This most curious and important discovery shews therefore both an entire separation of heat from light in the solar ray, and a very different degree of refrangibility of one from the other, which together go near to establish the separate identity of caloric and light, and cause precisely the same arguments used to demonstrate the materiality of light to apply to the materiality of heat.

These experiments of Dr. Herschel have been fully confirmed by Sir H. Englefield,^c whose apparatus was somewhat different and more accurate. The particulars are as follows: the coloured rays of the spectrum were successively and singly thrown on a lens (all the others being excluded by a screen) and a thermometer with a blackened ball was placed in its focus, and allowed to remain there some time after it had ceased to rise, that the full effect might be secured. Thus circumstanced it rose

In the blue ray from	55° to 56°
—— green ——	54 — 58
—— yellow ——	56 — 62
—— red ——	56 — 72
Quite out of visible light	61 — 79

These experiments were repeated several times, and in all with very closely corresponding results, and the most striking and novel phenomenon was manifest in all, namely, the *rise* of the thermometer when passed beyond the extreme point of the luminous spectrum on the red side, and its *fall* when again carried back into the red light. It is to be observed that as these experiments were made in a London atmosphere, in weather not uniformly bright, the numbers expressing the rise of the thermometer

^a Thompson's Chemistry.

^b Phil. Trans. for 1802.

^c Jour. Royal Instit. No. 10.

are only to be considered comparatively. So palpable however is the difference of heat between even the red part of the spectrum and the contiguous dark side, that on shutting the eyes and moving the hand through the spectrum parallel to the prismatic axis, a sensible encrease of temperature will without difficulty guide it to the point of greatest heat beyond the red side of the spectrum.

The rays of heat are of a much more extensive refrangibility than those of light. This is immediately shewn by the circumstance that in the solar prismatic spectrum there are no rays that do not heat, whereas the rays of light fall far short of the extreme point of the calorific rays, and even, as just mentioned, fall short of the highest heating point. Dr. Herschel estimates the base of the spectrum of heat to be to that of the spectrum of light as about $5\frac{1}{2}$ to 3, but the degree of dispersion of the heat-making rays differs so entirely from that of the rays of light, that neither do the mean nor the highest points of refrangibility agree, nor is there any obvious relation between the area of heat and that of illumination.

Radiant caloric appears to possess the same properties, and to be propagated according to the same laws whether transmitted from the sun or from any other heated body, and whether or not it be accompanied by light. Thus the heat radiating from boiling water is reflected, refracted, and otherwise propelled precisely in the same manner as solar heat. The following important properties the rays of heat possess in common with those of light.^a

They are subject to the laws of reflection.

They are subject to the laws of refraction.

They are of different refrangibility.

They are liable to be stopped in certain proportions when transmitted through diaphanous bodies.

They are liable to be scattered on rough surfaces.

Some of these properties require further illustration.

The concentration of heat produced by the reflection of the sun's rays from a concave mirror is too well known to need further description. It proves satisfactorily that heat when in conjunction with light, is, like light, capable of being reflected. The rays proceeding from a candle, ignited iron, and any other substance in luminous combustion are also well known to be capable of being reflected and concentrated into a focus by a mirror. But it is only com-

paratively of modern date that the *invisible* rays of heat have been found to obey the same law of reflection, from whatever heated body the radiations proceed. The reflection of invisible solar heat was ascertained by Dr. Herschel, by presenting to a plain mirror the part of the solar prismatic spectrum where the heat was the greatest (that is beyond the extremity of the luminous spectrum on the red side) and with proper precautions causing the reflected rays of heat to fall on a thermometer. By this, in ten minutes, four degrees encrease of heat was indicated, whilst another very delicate thermometer by the side of the first, but just out of the line of reflection, remained all the time quite stationary. Hence the reflection of the invisible solar rays is proved.

But it was from experiments with culinary or artificial fire, that this most curious property of the reflection of radiant heat was first ascertained. The following interesting experiments were made by M. Piçtet, on a plan suggested by M. de Saussure, who appears to have derived the first knowledge of the fact from M. Lambert. M. Piçtet* placed two concave tin mirrors opposite each other at a distance of 12 feet asunder. In the focus of one of the mirrors the bulb of a sensible thermometer was placed, and in the focus of the other was put the heated body which was the subject of experiment. By this ingenious arrangement a large portion of the radiant caloric proceeding from the heated body, if it followed the known laws of catoptrics, would first be thrown upon the mirror in whose focus it was placed, thence would be reflected in parallel rays to the surface of the opposite mirror, and from this would be concentrated into its focus where the thermometer ball was placed. This arrangement was well calculated to render sensible the effect of a heated body of very small dimensions. On putting an iron bullet heated below redness into one focus, the thermometer in the other rose 10.5 degrees (of Reaumur) in six minutes, beginning its rise the instant the ball was in its place. A lighted taper used instead of the ball had nearly the same effect. But to take away all possibility of the interference of light, a glass matras full of boiling water was now substituted, and in two minutes the thermometer rose $3\frac{1}{2}$ degrees of the same scale. When the bulb of the thermometer was blackened, the effect was proportionally greater. The rise begins the very instant that the heated body is put in its place. The distance of 69 feet pro-

* Herschel.

* Essai sur le Feu.

duced no ascertainable interval of time between the cause and effect, which is not surprising, since it is highly probable that the motion of calorific rays is full as rapid as those of light.

These most beautiful experiments, with many others on the propagation of heat, have been repeated with various modifications by Mr. Leslie,^f with an apparatus of equal simplicity and elegance, and with thermometers of a peculiar construction and admirable sensibility.

The important discoveries contained in this interesting research make it necessary to extend the subject of the propagation of radiant heat to the consideration of the power or aptitude of (comparatively) hot bodies to propel or discharge heat in a radiant form from their surfaces, and of (comparatively) cold bodies to receive and absorb caloric radiating to their surfaces. In the former case caloric passes out of a combined to a radiated state; in the latter, the contrary takes place. The beautiful experiments which we are about to relate shew a very uniform agreement between these two contrary powers, and prove that the power of absorbing radiant heat possessed by different bodies or surfaces of bodies, is exactly equivalent to their power of transmitting heat in a radiant form.

The apparatus used by Mr. Leslie was the following. A thermometer with a double bulb, constructed in such a manner that a rise or fall on the scale would take place only when the indicative bulb was exposed to a higher or lower temperature than the other bulb, or than the surrounding air. This the inventor terms a DIFFERENTIAL THERMOMETER, and its construction will be explained under that article. The peculiar advantage which it possesses, besides its extreme sensibility, is, that in using it the common temperature of the surrounding air may in general be disregarded, this being always the zero of the scale, whatever be the actual variation of heat in the surrounding atmosphere: and hence a much greater simplicity is introduced in these delicate researches. For the reflection of heat, mirrors were employed, generally of block-tin, highly polished, and hammered to fit a wooden gage, the segment of a parabolic curve, whereby much of the dispersion produced by a simple concave form was avoided, so that when exposed to the direct rays of the sun they collected them into a pretty distinct focus of about half an inch in diameter. The substance employed to generate the radiant heat was a hollow cubic tin canister, whose station was directly in front of the mirror of

its focal point, and when used, was filled with boiling water, and fitted with a common thermometer passing through a hole in the cover and immersed in the water. The cubical form of the canister allowed of four sides of perfectly equal dimensions, each of which, when turned to the mirror, afforded a heated surface for the transmission of radiant caloric, and they were occasionally coated with various substances to ascertain the effect of colour, polish, and the like, in retarding or promoting the radiation of the heat within.

Some of the principal experiments we shall relate.

The bulb of the thermometer being in the focus of the mirror, if the canister is filled with boiling water and set opposite to the mirror, generally at the distance of three feet, the liquor of the thermometer begins to rise immediately, and in a few minutes has attained its greatest point of elevation, after which it slowly sinks as the water cools, till at last it returns, in perhaps about two hours, to the standard of the atmosphere, at which point, whatever be the actual temperature, the differential thermometer remains at the zero of the scale. This experiment, like that of M. Picotet as above related, shews the simple reflection of caloric radiating from the surface of the heated canister. With a six-inch canister, three feet from the mirror, the total rise of the differential thermometer was about equivalent to 14.5° degrees of Fahrenheit. Mr. Leslie also found that in all cases the full effect of the radiant heat on his thermometer was exactly proportioned to the heat of the canister above that of the room. Thus if the water in the canister is at 200° and the room at 60° (making a difference of 140), and the full rise on the differential thermometer amounts to 84 degrees of any scale, a difference of 100 degrees will cause a rise of 60° in the same thermometer, for 140 is to 84 as 100 to 60 .

The effect of altering the surface of the heated body whence the radiations of heat originate, is shewn in a very striking manner by the following experiments. Of the four equal sides of the cubic tin canister, one was covered with lamp-black, a second with writing paper, a third with glass cemented on by pitch, and the fourth left unaltered. The canister being filled with boiling water, and each side being turned successively to the mirror, the effects were surprisingly different. The first or blackened side raised the thermometer 100° (of an arbitrary scale); the second or papered side,

^f Inquiry into the Nature of Heat.

about 98° ; the third, or glazed, gave 90° ; but the polished tin side gave only 12° . From this curious experiment it appears that a polished metallic surface has no more than about an eighth part of the power of propelling heat possessed by a soft unpolished surface.

To shew that this difference of the transmitting or propelling power was correlative with that of the receptive power, as abovementioned to be the case, the bulb of the thermometer was now coated with tinfoil pressed smoothly down, so as to imitate very exactly the polished surface of the canister. The blackened surface of the canister being now presented to the mirror (which produced an effect of 100 degrees on the plain bulb of the thermometer) now raised it only 20° ; and when the plain surface of the canister was presented (which before had given 12°) it now gave only about 2.5° .

The inference from these experiments is, first, that the propelling and absorbing powers of surfaces relatively to radiant caloric are always in the same proportion, and that this power is many times less in bright metallic surfaces, than even in glass, and still more in soft unpolished surfaces such as black paint or paper.

The power of absorbing, and of propelling or transmitting heat, being coexistent and correlative in the same substance, they must both be in direct opposition to that of reflecting heat, the surfaces which the most oppose the reception and propulsion of heat being those which reflect it the most powerfully. The experiments just related shew that the polished metallic surface of the canister with difficulty transmits caloric, and that the metallic coating of the thermometer bulb prevents its absorption of heat; the following experiments shew how much superior power of *reflecting* heat is possessed by a metallic over a glazed or any other surface.

In the place of the tin reflector (of the apparatus before described) substitute a concave glass mirror, and put the naked thermometer-bulb in its focus as before; then fill the canister with boiling water and present the blackened side. The effect will now be very small, but determinate. Rub off the silvering from the back of the mirror, and the effect remains the same. Roughen the back by grinding with emery, the same effect is produced. Cover the anterior surface of the mirror with Indian ink, and all effect on the thermometer ceases. Cover the face of the mirror with tinfoil, and the rise of the thermometer will now be ten times as much as with the smooth surface of glass. The same difference between the reflecting power of glass

and that of metal had been observed by M. Pictet, who ingeniously supposes that the radiant heat first penetrates the anterior or glass surface of the mirror, and proceeds (much obstructed) to the metallic coating on the back, from which it is reflected and passes back out of the anterior surface into the atmosphere. Hence the great loss of heat is accounted for by its double passage through the entire thickness of glass. But the circumstance that the reflecting power continues just the same with or without the silvering of the mirror at the back destroys this hypothesis, and hence the explanation will be, that glass being a better absorber of radiant caloric than polished metal, takes in the greater part, and reflects only a small portion from the surface, against which the radiant heat first strikes. Hence too by covering the glass with a soft coating of black ink, the absorbing power is still more encreased, and consequently the reflecting power proportionably diminished.

No delicacy of experiment is required to shew in a general way the vast superiority of metal over glass in reflecting heat. Thus if the commonest tin reflector, at all approaching to a concave or parabolic form, be held several feet from a large fire, and the finger put in the focus, a very considerable warmth will be perceived; whereas the best glass mirror of the same dimensions and at the same distance, will hardly collect in its focus heat enough to be felt.

The following scale of effect produced by the above apparatus of Mr. Leslie, will serve to give a clear idea of the subject. Oppose the bright side of the tin canister filled with hot water to a glass mirror, and coat the thermometer-bulb with tinfoil. Here the canister, the mirror, and the bulb are all in the most unfavourable circumstances for the transmission, reflection, and absorption of radiant caloric. The rise of the thermometer will be very small, call it equivalent to 1 degree. Then cover the face of the glass mirror with tin-foil, which will have the same effect as substituting a metallic mirror, and this reflexion will be so much encreased that the thermometer will rise to 10° . Then take off the tinfoil from the bulb, whereby its absorbing power will be encreased, and it will rise to 50° . Lastly, present the blackened side of the canister, which transmits caloric with the most ease, and the full effect will now be 400° , as every circumstance is now the most favourable to the transmission and reflection of heat.

For experiments where great nicety is not required, as polished metallic specula are

expensive, and even hammered tin reflectors not very easily procurable, a reflector cast of Paris plaster and gilt on its anterior surface^s will answer very well, and the reflection of heat from this cheap instrument will still be much greater than from any glass mirror of equal dimensions.

The above experiment of Mr. Leslie shew therefore a correspondence between the power of propelling and absorbing heat: a continuation of the same researches throw further light on the curious question how far the propulsion of heat is affected by the nature and condition of the propellent surface. A few only of many experiments can here be related. With the apparatus of the canister and mirror above described, the effect of the plain tin side in propelling caloric is equivalent to 12 degrees of the differential thermometer when that of the blackened side (assumed as a standard) is 100°. The tin being rubbed with mercury so as to be of a dull white, gave 14°, but being soaked with mercury so as to form almost a resplendent coating of this metal, gave 20°. Hence we may infer that the propellent power of mercury is about double that of tin.

The effect of the successive degrees of oxydation of the same metal is striking. A clean rough surface of lead produces 19° of the thermometer; the same, tarnished with a grey crust by exposure to air, gives 45°; a coating of minium gives 80°; sealing-wax and rosin each gives about 95°.

The degree of polish or evenness of surface also much influences its power of propelling caloric, which encreases in proportion as the surface is roughened. Thus the effect of smooth hammered tin being always 12°, when scraped to a bright but irregular surface it amounts to 16°; when ploughed by a small-toothed plane-iron, with intervals of $\frac{1}{16}$ of an inch between the teeth, the effect rises to 19°; when thoroughly filed over the whole surface it amounts to 26°. Thus if smooth tinfoil gives 12°, the same rubbed in one direction with sand-paper gives 22°. But if the scratches are much multiplied, an approach to smooth polish is made, and the effect is again diminished.

The *thickness* of the propellent surface, or more accurately the thickness of a stratum of matter applied to a heated surface and of a different nature from it, also in some cases considerably modifies the propellent power.

A small portion of liquefied jelly spread on a smooth surface of the tin canister, and dried to a very fine iridescent pellicle, gave 38° (the

effect of the unsmear'd tin being always 12°); a pellicle of four times the thickness gave 54°; a thick layer of isinglass gave about 80°. This encrease however has its limits, for after the thickness amounts to the thousandth part of an inch, the propellent power is not encreased by any subsequent additions. This rule does not apply however to any metallic coating applied to glass or other metal. The effect in this instance is purely that of the metal at the surface, and is not at all modified by the thickness. Thus tinfoil applied to glass appears to have the same propellent power as a solid plate of tin whose surface has the same density, smoothness, and polish as the foil, and a single thickness of gold leaf produces the same effect as any number of leaves.

The *colour* of the heated surface appears to modify in some degree its receptive and propulsive power with regard to caloric. Thus black seems to have these powers in the highest degree, the highest effect in the above experiments being produced by a coating of size and lamp-black, but as the nature of pigments varies extremely, some being simply vegetable matter, and many of them metallic oxyds, it is difficult to obtain any accurate results on this subject. Thus, white paper produces nearly the same effect as lamp-black, and stained paper nearly the same as white.

The modifications of the propulsive and absorbent power according to the nature, texture, and state of the surface of the propelling, or the absorbing body, are beautifully illustrated by extending the same experiments to the *reflection* of caloric. Here, as already mentioned, the range of the above effects will be entirely reversed, as the surfaces that propel and absorb heat the most readily are those which reflect it with the greatest difficulty, and vice versa.

The reflective power of different metals might be ascertained by causing reflectors of equal dimensions to be made of the respective metals, but as this method would be difficult and expensive, Mr. Leslie ingeniously took advantage of the secondary reflection produced by placing a circular flat plate or disk of the metal to be examined, parallel to the face of the tin reflector, and nearer than the proper focus. This by the laws of catoptrics (which apply equally to the propagation of heat) will produce a secondary reflection from the disk, whose focus will be situated as much before it as the focal point of the reflector is behind it. Under these circumstances the thermometer, whose bulb was placed

exactly in the secondary focus, was raised in the following degree by disks of different metals returning the reflected heat of the canister, viz. brass 100° ; silver 90° ; tinfoil 85° ; steel 70° ; lead 60° ; tinfoil made bright by the affusion of mercury 50° . A disk of glass produced only 10° , and coated with wax, only 5° .

Roughening the tin surface of the canister was found in the former experiments to *encrease* the propelling power: hence the same operation performed on a mirror lined with tinfoil *diminished* the reflecting power to nearly one-tenth of its former intensity.

A tin reflector coated with a pretty thick layer of tallow had its reflecting power reduced from 100° to 8° , but again encreased to about 40° when most of the tallow was melted off.

Tin reflectors were coated with isinglass by pouring a little of the liquefied jelly into the hollow of the mirror, and turning it round constantly till the whole surface appeared to be uniformly coated with it, which dried into a smooth and nearly transparent membrane. The reflecting power was immediately reduced by the wet jelly from 100° (the power of the clean reflector) to 31° , but as the coat of jelly gradually dried, the power again encreased gradually to about 72° . This shews very strikingly the effect of the thickness of the stratum, since in drying, it must gradually have shrunk, till at last it became only a fine film of membrane. An encreased quantity of jelly also diminished the reflecting power, but the exact law of diminution is not easily ascertainable.

As in the case of propelled caloric, a metallic coating, however thin, produced the same effect on the reflector as if it had been entirely made of the covering metal; so when the bulb of the thermometer was coated with a single thickness of gold-leaf, its absorbing power was so much lessened as to produce no more than about a fifth of its natural effect.

It has been mentioned that when radiant heat, from whatever source derived, is obstructed in its passage by any solid body, the portion which is not reflected from its surface enters its substance, combines with it, and then assumes a new form; so that the pulsatory energy which it received from the propellent surface is totally lost by this combination. In other words, the caloric is not *propelled* through a solid body, but unites with it in a different mode, and raises its temperature, till the solid substance becomes a new and secondary or derivative source of caloric radiations, which are again propelled from its surface, not according to the original pro-

pellent force, but according to that which belongs to the nature and condition of the surface of the secondary heated body.

This is also illustrated by very curious experiments taken from the same author. Some of them are the following:

Place the frame of a screen between the canister and the mirror (in the apparatus all along described), over which stretch any substance to be the subject of the experiment. The screen should be large enough totally to intercept all communication of heat between the canister and the mirror. When a thin sheet of tinfoil is the screen, the radiant heat from the canister is so compleatly intercepted that no sensible effect is produced on the thermometer bulb beyond it in the focus of the mirror.

Substitute a pane of glass to the tinfoil, and the effect produced on the thermometer will now be about 20° , the full effect without the enclosed screen being 100° .

Glass is permeated by light, which suffers however a certain diminution or absorption in its passage. But this diminution is proportionally the same whether the light is in a diffused or condensed state, and therefore is the same whether, in the above apparatus, the glass screen be more or less near to the radiating source. Not so with heat, for the rise of the thermometer is the greatest when the glass screen is close to the canister (not actually touching it) and diminishes in proportion as the screen is advanced towards the mirror. Hence it follows that the propagation of heat through glass is made in a different mode from that of light.

Cause two sheets of tin to be painted black on one side only, and put them in close contact with their bright sides outermost. No sensible effect will now be produced in the bulb of the thermometer. Invert the tin plates so that the painted sides are outermost, and an effect of 23° will follow. Remove one of the plates, and the thermometer will shew 4° .

This experiment well illustrates the nature of the propellent and absorbing powers of surfaces already described, since the substance of the screens is exactly the same, and only their relative position altered: and it is clear that the radiations only affect the surfaces of bodies, since when the screens are in close contact, the inner and touching surfaces of each produce no sensible alteration on the propulsive power, but communicate their heat by the conducting power. When one plate is removed, though the actual thickness of the screen is diminished one-half, one of the surfaces is now metallic,

and consequently propels caloric with much less force than when both outer surfaces were painted.

Place each half-blackened tin screen on separate frames; join them together, and the effect on the thermometer will be 23° ; put them two inches asunder, and the effect will not be perceptible. The screen the furthest from the canister in this case only receives a doubly derivative caloric (being propelled from the first screen, which is itself a secondary source) which is so much enfeebled in its passage as to be imperceptible by the thermometer.

From a number of experiments it is obvious that heat radiates from the surface of the propellant body, like light, not only in perpendicular but in divergent lines. It becomes a question whether the radiating or propulsive energy is at all modified by the direction which it takes from the propellant surface. Mr. Leslie found that the effect of a heated cubic canister was the greatest, when the radiating side was exactly parallel to the mirror, and decreased gradually when an oblique direction was given by turning it on its center, and thus preserving the same distance. The law of this decrease appears to be proportional to the degree of obliquity, whence it may be laid down as a general rule that the action of a heated surface is proportional to the sine of its inclination, and therefore is greatest in a direction perpendicular to the surface.

The times taken up by the respective cooling of heated bodies exposed to a cold atmosphere or any other elastic medium, equally illustrate all the preceding observations concerning the effect of surfaces in promoting or retarding the radiation of heat. Thus when a hollow tin ball is filled with hot water and set to cool in a tranquil atmosphere, if it takes 156 minutes to cool down to a given point when the surface is bright and clean, the same, painted with lamp-black, will cool to the given point in 81 minutes.^b This indeed does not accord with the proportional propulsive energy of these two opposite surfaces in the experiments of the reflexion of radiant caloric already mentioned; for in these it was found that the force of radiating caloric from these two surfaces was as 96 to 12, or eight times as strong in the blackened as in the bright metallic surface. Whereas the actual rate of cooling is only four to one, or four times as great in the painted as in the metallic ball. Some other cause than radiation must therefore act in this case, and must act nearly

equally upon both surfaces, since it tends to diminish the relative proportions between the cooling power of these two substances. This will be mentioned in the next section, when treating of the conducting power. The actual law of cooling that regulates all bodies immersed in a fluid medium, will be presently noticed.

Radiation of caloric has been observed to take place only in elastic mediums, or perhaps in a vacuum, but certainly not in water. To prove this, if the apparatus of the heated canister and mirror be immersed in water, no rise whatever takes place in the differential thermometer when placed in the focal point.ⁱ Likewise, a clean bright tin ball filled with hot water and immersed in cold water, cools down to a given point as soon when the surface is bright as when painted.

Several important practical inferences may be drawn from the properties of radiated caloric, and the power of different surfaces to propel, absorb, and reflect radiated heat. Many of these are in direct opposition to commonly received opinions. Thus in cases where it is required to preserve the heat of any substance confined in a metallic vessel, the external surface should be kept clean, bright, smooth and polished;^{*} on the other hand, if the object be to cool them quickly, the surface should be painted or tarnished, or covered with a thin layer of some soft unmetallic coating. For example, metallic pipes intended to convey steam uncondensed to a distance should be kept bright, or may advantageously be gilt, as the thinnest possible coat of gilding will answer the purpose of diminishing as much as possible the quantity of radiated caloric. On the contrary, metallic pipes or flues conveyed into a room with the view of warming it, should be rough, unpolished, tarnished, or better, painted.

Some limit however is put to the calculation of the gain or loss of caloric by radiation, by the circumstance that conducted caloric (which will presently be described) in very many cases has precisely an opposite range of action. Thus metallic bodies conduct heat with much more facility than glass or wood of equal thickness; and hence when a person touches a metallic vessel containing a hot liquid, the heat is so rapidly conducted to the finger as immediately to become intolerable; and yet, as has been fully shewn, the same vessel keeps its contained liquid much hotter in the air in a given time than a glass or wooden vessel of the same dimensions, which the hand could touch without uneasiness.

^a Leslie.ⁱ Leslie.^{*} Rumford.

So that the heat of the outside of any vessel to the touch is no other criterion of the ease with which heat radiates from it, than to make it probable that the surfaces which feel the hottest are from their nature those which retain heat the longest in the air, or any elastic medium.

The thickness of any vessel, more especially if as much as possible of it is made of light spongy materials, directly diminishes the conducting power, though it often encreases the radiating. Thus a metallic vessel will cool *faster* than before if wrapped round with a single fold of thin flannel, closely adhering to the surface, as will be seen by the following simple experiment. A thin hollow cylinder of tin-plate, of 2 inches diameter and 5 inches in height, quite bright and clean on the outside, was filled with hot water, and a thermometer bulb introduced in the middle of the water through a hole in the cork which fitted to the top. The heat of the water observed every five minutes from 195° was, successively, 195° — 187.5° — 180° — 173° . The same experiment repeated with every circumstance the same, except that the cylinder was closely wrapped round with a single fold of flannel, now gave 195° — 186° — 177.5° — 170° . So that in fifteen minutes the cylinder covered with flannel had lost 3 degrees more of heat than when uncovered. This is explained from the principle that the surface is changed from a metallic, to one of soft vegetable matter, which radiates heat with much more intensity: but if wrapped round with several folds of flannel loosely adhering, this encreased radiating power would be fully or more than counterbalanced by the greater difficulty which the enclosed heat would find in being conducted outwards through so great a thickness of a loose spongy material.

All that has been said about the power of surfaces to promote or retard the radiation of caloric from them when hotter than the surrounding air (and equally the absorption and reflexion of radiated caloric) apply exactly, changing the circumstances, to the radiation of cold, meaning by this term a temperature lower than that of the surrounding atmosphere. Thus iced water contained in a bright clean metallic vessel and exposed to a warm air, retains its cold longer (or, were cold, a positive substance we should say the metallic surface *propels frigorific rays* with less force) than if the outside of the vessel were painted or even tarnished. But this leads to the curious enquiry relating to

The Radiation and Reflexion of Cold.

Nothing appears at first sight more directly

contradictory to the common opinion of cold being only relative, and only a negative term implying the abstraction of heat, than the facts which shew the apparent radiation, absorption and reflexion of cold; the evidence of which stands on the same ground as the corresponding motions of heat already described, namely, on the rise or fall of the thermometer. If the *rise* of the liquor on the scale of a thermometer whose bulb is placed in the focus of a mirror, be considered as a proof of the propulsion of certain calorific rays from a distant heated surface, and their subsequent reflexion according to the laws of catoptrics; the *sinking* of the same thermometer liquor under similar circumstances of position, when the surface which before was sensibly hotter than the atmosphere is now sensibly colder, would seem from a parity of reasoning to indicate the propulsion and reflexion of frigorific rays. Nor can we consider this question as at all determined, though an ingenious hypothesis has been advanced by M. Prevost, which goes a considerable way to reconcile the apparent contradiction of the doctrine of the unity of heat and cold. The leading facts however are the following.

It is singular that the reflexion of cold should have been accidentally discovered and decidedly announced about the year 1667 by the members of the Florentine Academy del Cimento, without any further prosecution of so curious a fact.

The experiment is the following.¹ A mass of ice of about 500 lb. was set some distance before a concave glass mirror, and the bulb of a spirit thermometer put in the focus to try whether cold would be reflected. Immediately the spirit of the thermometer began to sink, and fell several degrees. To prove that this was not merely owing to the contiguity of the ice, the surface of the mirror was covered with a cloth to prevent the reflexion, and the thermometer again rose. No further inference is drawn from this experiment, and the author of it seemed even to doubt of the reality of the reflexion, and to be disposed to impute it to some other unknown cause.

This experiment was repeated in a much more accurate way by M. Pictet.^m The apparatus which he used was the same as that before described, as employed for the reflexion of heat; that is, two tin mirrors placed directly opposite each other at some distance, in the focus of one of which was placed the bulb of a very sensible thermometer, and in the other the

¹ Waller's Translation, p. 13.

^m Essai sur le Feu.

vessel intended to produce the heat or cold. In this instance this latter was a matrafs full of snow: the mirrors were separated to the distance of $10\frac{1}{2}$ feet. At the instant the matrafs was placed in one focus, the thermometer in the opposite focus began to sink, and descended several degrees. When stationary, nitrous acid was poured on the snow, which produced a cold of much greater intensity, and the thermometer in consequence immediately descended several degrees lower. When taken out of the focus, it again rose to the common temperature.

Mr. Leslie also found, not only the same effect in his experiment, but that the action of a cold-radiating surface upon the tin reflector produced exactly the same proportional effect upon the differential thermometer as the hot radiating surface, only in the opposite direction of the scale. The differential thermometer, which is always at zero when both bulbs are equally heated, is beautifully calculated to shew this striking experiment. Thus if the difference of temperature between the heat-radiating substance and the atmosphere be 60 degrees, and if this raises the thermometer 45 degrees, the same difference between the cold-radiating substance and the atmosphere will sink the thermometer 45 degrees, and so in proportion; so that a cold of 16 degrees will sink the thermometer 12 degrees, for $60 : 45 :: 16 : 12$.

The range of these experiments on cold is necessarily more limited than that of heat, for it is not easy to keep up a cold less than 0° (Fahr.) in any vessel, for a moderate length of time, which is only about 60° below the average temperature of a room; whereas the heat of boiling water is 150° above this average. Besides, a source of error takes place in estimating the propulsive energy of a cold substance when at a very low temperature, which is, the constant condensation of the moisture of the atmosphere on the surface, except the air is uncommonly dry, and this introduces an extraneous substance into the comparative experiments.

The theoretical explanation of these curious facts leads us immediately to the consideration of *The Equilibrium of Radiant Caloric*.

The simplest explanation of what passes when a heated body cools in a cold medium and raises the temperature of the surrounding substances, is to suppose a mere efflux of caloric from the hotter to the cooler bodies, radiating with more or less force according to the greater or less difference between the thermometrical heat of the two, and the nature of the heated surface, with

regard to its heat-propelling quality. This would explain without difficulty the reflexion of heat in the experiments already related, but would not apply with equal ease to the reflexion of cold. For supposing (as the simplest case) a canister filled with iced water at 32° , standing before a tin reflector, and a thermometer bulb in the focus, with the common temperature of 60° ; if no other radiation takes place than that from the hotter bodies to the colder one, the cold canister would merely make a kind of void or gulph, into which the thermometer bulb, the reflector, and the ambient air would all pour their excess of heat by direct radiation in the shortest path, and not in any other direction; nor could any retrogradation or reflexion of rays take place between the thermometer and the mirror.^a Hence the presence of the mirror could make no difference in the temperature of the thermometer, and its focal point would not be colder than any other contiguous spot.

The very ingenious theory of M. Prevost reconciles this difficulty without requiring the supposition of positive radiations of cold; though this last hypothesis will certainly apply with equal force to all the circumstances of the reflexion of cold as to those of heat.

According to M. Prevost,^o heat, when uncombined, is a subtile fluid, of extreme mobility, dispersing its particles in every direction, which exist in that state of mutual repulsion or separation, that contrary or different currents may cross each other, like those of light, without disturbance or interference. This constitution of heat being admitted, a constant interchange of radiations of heat is kept up between all substances placed within the sphere of mutual influence, whether hot or (comparatively) cold. The interchanges are equal when the substances have the same thermometrical temperature, and the mutual *tension of heat* is then in equilibrium. A hot body, in cooling, parts with more caloric than it receives, and its excess of heat disturbs the tension of heat between it and the surrounding bodies, till the inequality of the interchanges has restored the equilibrium. On the other hand a comparatively cold body, in heating, receives more caloric than it parts with, as long as the equilibrium is restoring.

To apply this hypothesis to the two opposite experiments of the reflexion of heat and of cold.

Where (in the apparatus of Mr. Leslie so often referred to) the canister is filled with boiling water, and therefore hotter than the surrounding air and the mirror, the interchanges

^a Prevost, Ph. Transf. 1802.

^o Recherches Physico-Mechaniques sur la Chaleur, & Ph. Transf. 1802.

of caloric are unequal, and (comparatively) hot rays proceed from the canister. As the rays from this quarter are the only ones which can produce any effect in the focus of the mirror, the temperature of the focus, like and superior in degree to the rays from the canister, is hot; and the thermometer proportionally raised. On the other hand, when the canister is filled with ice mutual interchanges of caloric take place, as before, between all the substances concerned in the experiment; but the rays that proceed from the canister are now (comparatively) cold, and hence a similar and more intense cold is produced in the focus, which is shewn by the sinking of the thermometer.

It does not appear that any experimental proof can be devised to confirm or disprove the truth of the above hypothesis of the constant and mutual radiations of caloric between substances whose thermometrical temperature is the same; since the thermometer is the chief, if not the only instrument, which we can apply to detect the passage of heat, and it is obvious that it only indicates the disturbance of the equilibrium, and not the mutual interchanges that maintain this equilibrium. The relation and correspondence between the powers of propelling and of absorbing caloric possessed by different surfaces, and so beautifully illustrated by Mr. Leslie's experiments, may perhaps be a support to the above hypothesis, since it reconciles the maintenance of the equilibrium of the conducted heat in liquids, however enclosed by vessels of any solid materials, and in solids themselves, with that of the radiant heat of the surrounding atmosphere.

The cooling of hot bodies by simple radiation into the surrounding cold medium, and the heating of cold bodies by absorption from the surrounding hot medium, are regulated by certain laws, which have been well explained by the experiment of M. Kraft and Richman.* The most important of these is the following. When a hot body is immersed in a cold medium of uniform temperature (in the common atmosphere for example) the loss of heat proceeds in an inverse geometrical progression, whilst the time proceeds in a direct arithmetical progression. The same rule also applies to the heating of a cold body in an uniformly hot medium. For instance, supposing the propulsion of caloric from the heated body is of such an intensity that one-tenth of the whole excess of heat, above that of the surrounding medium, is lost in one minute; then, at the end of that time

there will remain $\frac{9}{10}$ of the whole. After the second minute, the tenth of the heat that was left is dissipated, and hence there now remains in the heated body $\frac{9}{10}$ of $\frac{9}{10}$ or $(\frac{9}{10})^2$. After the third minute there will remain $\frac{9}{10}$ of $(\frac{9}{10})^2$ or $(\frac{9}{10})^3$. After the fourth minute $(\frac{9}{10})^4$, and so on, the quantity of heat decreasing in geometrical progression, whilst the time increases in arithmetical progression.

Hence too it appears that whilst the equilibrium of heat is restoring, the actual quantity of caloric passing from the hotter to the colder body is constantly decreasing in equal times: thus if the first excess of heat be equivalent to 100, the first minute will subtract 10, the second minute 9, the third 8.1, the fourth 7.29, and so on in proportion, always leaving $\frac{9}{10}$ of the last residue. Hence, after 10 minutes have elapsed (at which time the whole excess of heat would have been spent, had the actual loss been uniformly the same as during the first minute) more than one-third of the original 100 parts, or 34.86 parts, still remain in the heated body. This encreasing slowness of heating or cooling, as it approaches the equilibrium, is a matter of common observation in numberless experiments. Thus if a thermometer be plunged in boiling water and then exposed to the air, it will sink at first visibly and rapidly, but this sinking will soon be found more and more retarded, and at last many minutes will elapse before it has arrived at the exact temperature of the air. The same of cold bodies, in acquiring the heat of the surrounding medium.

The same reasoning will apply to the hypothesis of the mutual interchange of caloric between bodies, whatever be their thermometrical temperature. For if a cold body is exposed to a hot medium, the heat of this last may be considered as divided into two parts, that which is equal to the cold body, and that which forms the excess. With regard to the first, as it only serves to equalize what it receives from the cold body, and to produce an equilibrium, it is put out of the question, and it is only the excess to which the laws of progressive diminution can be applied.†

The investigation of the above law of Richman becomes somewhat more complex when both the hot and the cold body are changing their temperature, the former by losing, the latter by gaining caloric; for in the heating or cooling of any substance in the atmosphere, the proportion between the bulk of the body and the medium

* N. Comin. Acad. Petrop.

† Prevost.

in which it is immersed is so small, that in most instances the temperature of the medium may be considered as stationary.

Though the radiation of caloric generally takes place in the medium of the atmosphere, and certainly neither in dense fluids nor in solids, it does not appear that any medium is necessary to convey the radiations of heat. Certain it is that according to apparently accurate experiments, caloric does pass directly through the torricellian vacuum, though it is physically impossible to confine a thermometer bulb within a vacuum without some necessary communication with the external apparatus through the stem of the instrument, so as to be able to convey heat by a different path than that of radiation. It appears that caloric is capable of radiating through a vacuum, when the sides of the vessel that forms the vacuum have a higher temperature than the vacuum itself, or than any substance placed in it; or vice versa, when the enclosed substance is hotter than the sides of the confining vessel. Count Rumford's experiments on the comparative conducting power of air and a vacuum are much to the point.

Count Rumford very judiciously rejected the common air-pump receivers, as it is well known that none will ensure a perfect vacuum, both on account of the impossibility of rigorously exhausting all the air, and because of the watery vapour which always arises from the moisture and the oil of the apparatus, and which, like rarefied air, is a conductor of heat. He therefore employed the torricellian or barometrical vacuum, and by ingenious management soldered the stem of a thermometer tube into that of a glass bulb, which formed the vacuum, so that after filling with mercury, inverting the tube, and fusing together with a blowpipe the two stems, a complete insulated vacuum was left in the larger glass ball, with the bulb of a fine thermometer enclosed in the centre.

This apparatus was then immersed in warm water of a certain temperature to become uniformly heated, and then taken out and suddenly plunged in water at the boiling point, and kept at this heat during the whole of the experiment. The consequence was a gradual but slow rise of the enclosed thermometer during the whole time of immersion. The minute particulars need not be related, it is sufficient to observe that from 72.5° it rose in 1 min. 30 sec. to 81.5° , in 4 min. to 133° , and in 5 minutes to 141° . On admitting air to the same apparatus and repeating the immersion, the thermometer now rose

to the same points in a much shorter time, requiring respectively only 45 sec., 2 min. 10 sec., and 2 min. 40 sec.

The same kind of experiments were repeated with a more delicate apparatus, in which the communication between the thermometer and the external part of the apparatus was only a silk thread, and still the external heat arrived at the enclosed thermometer through the vacuum in progressive steps, and by reversing the experiment the acquired heat escaped from the thermometer to the external air.

By a considerable agreement of several experiments, Count Rumford concludes that the conducting power of a vacuum compared with that of the same extent of air perfectly at rest, is as 702 to 1000 nearly; for in the above experiments the quantity of heat communicated being equal, the intensity of the communication is inversely as the times.

But, as will be seen in the next section, it is difficult to make an estimate of the true conducting power of air distinct from that of the intensity with which caloric radiates through this medium, and therefore these experiments are only satisfactory as to the leading facts that caloric will pass through a vacuum, though with less rapidity than through air. It would be an interesting subject for experiment (though not easily managed) to ascertain how much the nature of the propelling surface affects the radiation of heat through a torricellian vacuum.

OF CONDUCTED CALORIC.

All bodies in nature are pervious to caloric, for no substance has ever been discovered which will for any length of time retain or confine that modification of heat and of cold which is sensible to the feelings and to the thermometer. But caloric is found to *radiate* through no other medium than the aeriform, consequently its passage through solids and liquids must be performed in a different manner; and even through air it does not entirely pass by radiation, since the state of the air as to density, moisture, motion, &c. is found to make a very decided difference in the ease with which heat pervades it.

When heat combines with any substance, the first effect is to expand it in every dimension, and this law is so universal as not to have a single proper exception. When any portion of a solid body is expanded, the only effect can be to produce a mutual recession of the particles acted on, and not a displacement of their comparative juxtaposition. If a perpendicular bar

of metal were made, the upper half of iron, and the lower of copper, and heat applied from beneath, no expansion of the lower portion could cause a mixture of the two metals, or a passage of one through the other. But quite the reverse happens when a liquid or gaseous body is partially heated; for being composed of fluid particles of great mobility, those that receive the first impression of heat and become expanded by it, acquire thereby a comparative levity, their specific gravity being diminished, and, if at the lower part of the mass, they immediately rise through the cooler portion to the surface, giving off in their passage more or less of their acquired heat to the particles of the cooler fluid with which they successively come in contact.

This essential difference in the mode of communication of heat renders it necessary to consider separately its passage through solids; and it would be even convenient in philosophical language to distinguish these very different motions of caloric by appropriate terms.

Of the Propagation of Heat in Solids.

When a solid body (a bar of metal for example) is exposed to the influence of any source of heat, this last pervades the metal, not with the immeasurable velocity of radiant heat, but with a slow and gradual progress, from the nearest to the most remote part; and if the heat be below fusion, producing no other apparent effect than expansion, and a somewhat different degree of cohesion of the particles of the metal. As radiant heat may be considered as caloric in its state of the greatest freedom, and the most uncombined, and as then it is found to move with a velocity utterly incalculable by any experiment, it must follow that the extreme retardation of its motion in passing through a solid is owing to a successive combination with all the particles or strata of particles which oppose its progress. Hence the particles of solid matter must have an affinity for caloric to be able to detain it for (comparatively) so great a length of time; and as this time is in no degree regulated by the specific gravity or density of the solid, that is by the supposed number of integrant particles of which it is composed, it seems evident that each substance has its peculiar and relative force of affinity with caloric. This force of affinity is obviously in direct opposition to its conducting power, for the greater force it exerts in detaining caloric, the less easily will it conduct, or allow the passage of caloric through its substance. Hence too the terms *good* or *bad conductors*; the former term being applied to

those bodies that have the weakest affinity for heat; the latter, to the strongest.

The passage of conducted heat through a body has its limits. Owing to the affinity between the two, a certain portion of the caloric is detained within the substance heated, and the expansion produced by the combination seems to assist in this detention. We in fact find that if one end of a very long bar be heated moderately and for a short time only, the heat is sensibly conducted only to a small distance, and in a constantly diminishing intensity. There is no good reason however to suppose that any of the acquired caloric is permanently detained in the bar, after the heated end has returned to the common temperature and the whole has contracted to its original dimensions. The intensity of conducted heat, and the distance to which it may be propagated, are also determined by the temperature at which the substance begins to melt, consume, or to undergo any other chemical change; for when this occurs, all the surplus heat above this point is employed in the chemical changes that are going on, and does not materially add to the quantity that passes off by the conducting power. Therefore (other things being the same) an indefinite intensity of heat will pass to a greater distance through a less than a more fusible metal, and further through an incombustible than a combustible substance.

Though caloric is capable of passing through solids in every direction, it appears that it more readily proceeds upwards than downwards. The experiments of M. Picot confirm this opinion, which has long been entertained. The apparatus employed by this very able experimenter was a glass tube about 4 feet long, containing a cylindrical bar of copper, hollowed a little at top and bottom, to receive the bulbs of two fine thermometers. The bar and tube were suspended vertically, and the bar was heated exactly in the middle by the sun's rays thrown upon it, and the exact spot was secured by enclosing the whole apparatus in a wooden frame, perforated at the place on which the heat was to fall. Moreover the glass was exhausted of its air, to a trifling residue, by a good air-pump, otherwise the mere ascent of the heated air in contact with the copper bar would certainly heat the upper part sooner than the lower, and defeat the object of the experiment. On heating the middle of the bar and observing the times required to raise the touching thermometers to the same heights, it was found that the upper one was considerably sooner heated than

the lower, and on changing the thermometers, that which was now at the top of the bar rose the highest in equal times as before. Also on observing the comparative rates of cooling, the difference was still more striking; for whilst the lower thermometer rapidly cooled, the upper one for some time did not sink at all, its loss of heat being exactly balanced by the influx from the lower part of the bar.

The above experiment cannot be considered as quite accurate, as no air-pump vacuum is a perfect one, and even if free from air it still contains some vaporous moisture, which is itself a conductor of caloric; and therefore the source of error intended to be avoided by the air-pump is not entirely removed. Another difficulty arises from the extreme difficulty of ensuring exactly the same extent and accuracy of contact of the upper and lower thermometer bulbs with the solid copper bar; but with all these deductions we may still consider it as nearly certain that caloric is more readily conveyed through solids in an upward than in any other direction. In the same apparatus another upper and lower thermometer were suspended, so as nearly, but not quite, to touch the heated metal, and therefore were insulated in a vacuum. The great sluggishness of their rise and fall, compared with the two that actually touched the heated bar, shewed (what has already been mentioned) the difficulty with which caloric radiates through a vacuum.

Metals are by far the best solid conductors that we are acquainted with. Every one knows that if one end of a short slender iron rod be thrust in the fire, the other end soon becomes intolerably hot to the fingers; whereas the same length of a similar wooden rod may be held without any inconvenience, and may even be consumed to within nearly a quarter of an inch of the fingers that hold the other extremity without burning them. The comparative conducting power of different substances is ingeniously shewn in the following way. Take short thin rods, of equal size and length, of any of the different metals, of glass, and any other substance required; coat one of the ends by dipping it into melted wax or tallow, and immerse the other into boiling water, or any other hot medium to which they will all be equally exposed. After a while the wax will

melt, first from the metallic rods in the order of their conducting power, then from the glass or other substance used, and the comparative times required to melt the wax from the respective rods will give their comparative conducting power.

In this manner Dr. Ingenhouz^{*} found the comparative conducting power between several metals to be in the following order: silver, gold; copper and tin nearly equal; platina, iron, steel and lead, all much inferior to the others. Hence the conducting power by no means corresponds with the density, tenacity, oxidability, fusibility, or any known quality common to all metals.

Next to metals, stones, glass, and hard earthy substances or compounds appear to have the greatest conducting power.

The conducting power of several woods has been ascertained with apparent skill and accuracy by Mayer, professor at Erlangen.[†]

Balls of the different woods were turned of the same diameter, and hollowed out so as just to admit the bulb of a fine thermometer. These balls were first dried in a gentle stove-heat for several days, and then heated uniformly to a certain point, and brought into a cold room without a fire. The respective times taken by each ball to cool to certain fixed points indicated inversely their comparative conducting power. A correction became necessary however on account of the unequal shrinkage of the balls during the drying. This was easily calculated from the law that in vessels of the same substance the comparative time of heating or cooling is at the diameter of the vessel. The balls being thus reduced by calculation to the same dimensions, the times of cooling from one given point to another were determined by the number of vibrations of a pendulum, which of course would be inversely as the conducting power. Elm wood was taken as a standard, to which all the others were first referred, and afterwards referred to that of water, whose conducting power was found by confining it in a hollow glass ball of the same dimensions as the wooden one, and deducting the separate effect of the glass. The specific gravity of the different woods was also ascertained, which is worth notice, as it shews some kind of accord between it and the conducting power, inversely, though not with much proportional accuracy.

^{*} J. Phys. tom. 34.

[†] An. Chim. tom. 30. from Crell's Journal, 1798.

The following is the comparative table.

	Conducting power.	Specific gravity.
Water	10.	1.000
Ebony wood	21.7	1.054
Apple-tree	27.4	0.639
Ash	30.8	0.631
Beech	32.1	0.692
Hornbeam	32.3	0.690
Plumb-tree	32.5	0.687
Elm	32.5	0.646
Oak	32.6	0.668
Pear-tree	33.2	0.603
Birch	34.1	0.608
Silver fir	37.5	0.495
Alder	38.4	0.484
Scotch fir	38.6	0.408
Norway spruce	38.9	0.447
Lime	39.0	0.408

It will be seen by inspecting the above table that the order in which they are given is directly as the conducting power, and inversely as the specific gravity, so that the lime, for example, which is less than half the weight of the ebony, has nearly twice the conducting power; which being inversely as the times, it follows that if 39 portions of time are employed in the passage of a certain quantity of thermometrical heat through ebony wood, only 21.5 similar portions of time would be required to conduct the same quantity of heat through an equal bulk of lime tree wood.

These results, if accurate, are very curious, for it is commonly observed that, *ceteris paribus*, substances of a light porous texture are worse conductors of heat than those that are dense and close-grained; whence we may infer (what indeed has been observed by Count Rumford and other philosophers) that mere porosity of texture is not necessarily connected with a retardation of the passage of heat, but in as far as it allows of the detention and adhesion of numerous particles of air, which elastic fluid, when at rest, is known to be one of the worst conductors in nature. Now it does not appear that the lighter woods contain more interstitial air than the heavier.

The interesting experiments of Count Rumford on the conducting power of various animal and vegetable substances used in cloathing, and on the natural coverings of animals, may here be shortly mentioned. * The instrument employed was very simple; it consisted of a mercurial thermometer, divided according to Reaumur into 80 degrees from freezing to boiling water, and inclosed in a large glass tube, with

a bulb of the same shape with the thermometer, but wide enough to allow of about an inch of vacant space on all sides between the two. The upper end of the thermometer passed through a hole of the same cork which closed its investing tube, and which kept it fixed in its proper situation, at the same time that the air contained in the interstitial space was by this means preserved at rest. The space between the two was the place in which the various substances for experiment were introduced, and their conducting power was ascertained by the time at which the thermometer, previously heated to 75 of the scale, fell to determinate points when exposed to a cold atmosphere. Thus situated, it is obvious that the substances introduced in the intermediate space between the two glasses would retard the sinking of the thermometer in inverse proportion to their power of conducting heat; and when in the comparative trials, equal points of the thermometer were taken, the times required to sink to these given points would give respectively the inverse conducting power of the substances under experiment. It is to be observed that part of the communication of heat, both from the thermometer to the outer glass, and from this last to the external air, was made by radiation, but in these experiments no material source of error probably arose from this circumstance. The substances introduced were pushed down by a brass wire, and distributed as equally as possible through the vacant space. The conducting power of this space, that is of the atmospherical air filling it, was first ascertained as a standard of comparison. The substances employed were raw Silk, Sheep's Wool, Cotton Wool, fine Lint, Beaver's Fur, Hare's Fur, and Eider Down, and the quantities of each were of equal weight. But the times required for the cooling of the thermometer surrounded with each of these substances were much more equal than was expected, therefore we shall only give the two the most differing, and air which was the standard.

Heat lost.	Air.	Fine lint 16 grains	Eider down 16 grains.
70°	—	—	—
60°	38"	80"	98"
50°	46	93	116
40°	59	115	146
30°	80	150	192
20°	122	218	268
10°	231	376	485
	576	1032	1305

* Ph. Trans. 1792.

Hence it appears that when a heated thermometer surrounded by about an inch in thickness of confined air takes 576 seconds to cool 60 degrees of Reaumur (135° Fahr.) it will take 1032 seconds to cool to the same point when 16 grains of lint are diffused through the confined air, and 1305 seconds when the same weight of eider down is used; so that, as the conducting power is inversely as the times, if the power of air be reckoned as 1000, that of the lint will be 558, and of the eider down 441.

But lint, eider down, fur, and similar flocculent substances may be considered as so many compounds of fine solid matter, with air inseparably adhering to them, and filling all their interstices, and their true conducting power, distinct from that of the air they contain, cannot be determined by such experiments as these have related.

The conducting power of these substances is further diminished by the closeness with which their particles are heaped together, at least to a certain limit, provided this compression does not proceed to alter their texture, which again would have a contrary effect. Thus Count Rumford found that when the same space which in the above experiment was occupied by 16 grains of eider-down, was filled, first with 32 grains, and then with 64 grains, the times employed in the passage of the 60 degrees of heat were successively increased from 1304 seconds to 1472", and 1615".

On the other hand, to shew the effect of mere *texture*, similar comparative trials were made of the conducting power of equal weights of raw silk, of ravelings of white taffeta, and of common sewing silk, of which the first has the finest fibre, the second less fine, and the third, from being more twisted and harder, is much coarser. The difference between these three modifications of the same substance is very striking, the raw silk detaining the heat for 1284 seconds, the taffeta ravelings 1169", and the silk thread only 917".

Hence as a general inference it may be observed that, as far as the mere conducting power of animal and vegetable fibre is concerned the substances that detain heat (or cold) the longest, that is, that have the least conducting power, or are the *worst conductors*, are those in which the fibres are the finest and the most condensed, provided that this condensation does not amount to that degree which would expel the interstitial air. But again, the surface immediately in contact with the outer air, parts with heat largely by radiation, as well as by the

true conducting power of air, and therefore the superior power of propelling caloric possessed by unequal and soft substances, over those that are hard, smooth, and polished, and which acts quite in a contrary way to the conducting power, must always be taken into consideration.

Of the Conducting Power of Air.

It has been already observed that when a heated substance is freely exposed to the air (or any aeriform medium) it parts with its excess of heat very largely by *radiation*, which is more or less intense according to the degree of the excess of heat, the nature of the surface in immediate contact with air, and the like; but radiation is not the only way in which heat is lost, for much of it passes off by the conducting or more properly the *carrying* power of the air itself. This is amply proved by the vast effect which agitation of the air produces in increasing the rapidity of cooling, which is readily explained by supposing that the particles of cold air when they come successively in contact with the heated surface, absorb part of the heat, and thus convey it away into the distant atmosphere. This kind of conveyance of heat therefore differs both from radiation, which is propagated to an immense distance in an instant of time, and from the slow and successive mode in which heat is conducted through solids, pervading particle after particle, and as it were saturating one stratum of particles before it proceeds to the next. Here on the other hand (and the same with liquid mediums) as the heat is conveyed along with the particles of the air with which it unites, its motion is precisely that of these particles, faster or slower according to the degree in which it expands them, and the buoyancy which it thus imparts, and also according to the force of any other propelling power which the air may have received. We shall find therefore that cool air conveys heat from a hot surface in direct proportion both to the rapidity with which it is renewed, and to its coldness when it strikes the heated body.

The cold produced by sweeping winds is a matter of common observation, but it is better to have recourse to direct experiment. The following is easily performed. Fill a glass matras, or any other vessel whatever, with boiling water, introduce a thermometer, and simply put it in the body of a blast furnace (without fire) and observe the point to which it cools in a given time. Afterwards repeat the observation with the same vessel, in the same situation, and with no other difference but that of working the bellows during an equal time, and the

difference of cooling will be very striking. In the former case if the water cools from 188° to 180° , by simple exposure for five minutes, it may be sunk in the latter case from 188° to 170° by a strong blast for the same time. The comparison will be better if instead of equal times, equal losses of heat are observed, and then the comparative rate of cooling will be inversely as the times. Now there is no reason to doubt that the radiation from the hot surface is the same in both circumstances, and therefore the difference must be owing to the superior quantity of caloric conveyed away by the rapid motion of the air.

We find too that air has no cooling or heating effect on a *dry* surface, unless it be colder or hotter than the substance on which it plays. Thus if the bulb of a thermometer of the temperature of the surrounding air be wiped perfectly dry, and the stream from a bellows be directed on it, no rise or fall of the mercury ensues: but on the other hand a stream of warm air directed on a piece of ice will melt it much faster than simple exposure to an equally warm atmosphere. In all these cases the subject of experiment is supposed to be *dry*, for if moisture be present, the increased evaporation produced by an augmented velocity of air will at all times abstract a large portion of heat, as will be further explained.

Mr. Leslie's experiments on this subject are curious and precise. A thin hollow globe of bright tinned iron, drawn into a fine neck through which a thermometer was inserted, was filled with hot water, and suffered to cool to a certain point without disturbance in a close room without a fire, the temperature of which was perfectly steady. The same experiment was repeated with no other difference than that the outside of the vessel was covered with black paint, the effect of which (as mentioned under the head of radiant caloric) would be to increase, to about eight times, the energy of the caloric radiated from the surface, the same being ascertained by the effect of the reflection of radiated caloric from a distant concave tin reflector. The bright ball actually cooled to a given point in 156 minutes, whilst the painted ball cooled

to the same point in only 81 minutes. The difference between these two numbers is sufficiently striking, but very far short of what would have happened had the loss of heat been occasioned by mere radiation, since the effect of this latter is eight times more in the painted than the metallic surface, whereas in this case it is only about double. Therefore when a heated substance is exposed to a free atmosphere, though as much at rest as a close room and an equal temperature will ensure, a large portion of the cooling effect is to be attributed to the conducting power of the surrounding air and the motion excited in it by the heated body itself, as well as the radiating power.

An increase in the motion of the air still further illustrates this. The same bright tin ball, and another similar ball, painted, were exposed in the evening (when the heating effect of the atmospherical reflection would be scarcely felt more on the black than the metallic surface) to the action of a gentle wind out of doors under perfectly similar circumstances. The same loss of heat as in the former experiment was now produced in the bright ball in 44 minutes, and in the painted ball in 35'. A pretty strong breeze in another experiment reduced the respective times to 23' and $20\frac{1}{4}'$. A vehement wind brought them still further down to $9\frac{1}{2}'$ and 9'. These comparative experiments, and the inferences deduced from them by calculating the entire range of cooling on the supposition of an uniformly equal loss of heat,* point out two important circumstances, the one, that the actual rate of cooling is most materially affected by the motion of the air; and the other, that the more rapid the motion of the air is, the less is the comparative effect of the nature of the heated surface: or in other words, that the proper conducting power of air acts apparently with equal energy on all surfaces, and therefore by abstracting heat so powerfully it uniformly diminishes, and finally renders almost insensible the peculiar differences of the radiating process. The above experiments will be better seen in a tabular form.

An equal loss of heat was experienced by the

minutes.	minutes.	
bright ball in 156	and by the painted ball in 81	(which is as 1000 : 519) in a close room.
44	35	(1000 : 795) in a gentle breeze.
23	$20\frac{1}{4}$	(1000 : 880) in a strong breeze.
$9\frac{1}{2}$	9	(1000 : 947) in a violent wind.

* Leslie, p. 268.

Where the temperature of the heated body is much above that of the cold medium, a similar effect is produced to that of agitating the air, that is, in tending to encrease and at the same time to equalize the rate of cooling of the opposite surfaces of metal and paint. In fact an actual encrease of agitation in the air is thereby produced, since the operation of any hot body must be to cause a constant ascending current of hot, and therefore light, air, in proportion as it receives caloric by contact with or proximity to the source of heat; consequently, the greater the degree of positive heat, and the more rapid will be the current of air.

It is also obvious that the same effect of encreasing the successive contacts of air is produced by agitating the heated body in still air, as by agitating the air against the heated body when at rest. Hence the common practice of hastening the cooling of any substance by waving it backwards and forwards, and it appears that the refrigerant power of air is always (other circumstances being the same) in exact proportion to its velocity.

The conducting power of air is diminished by rarefaction, so that whatever has a tendency to dilate air, proportionally lessens its power of conveying caloric. This diminution proceeds regularly till a complete vacuum is formed, which, as already mentioned, is a still worse conductor of heat than any kind of air, however dilated. Every substance which when converted to vapor produces a dilatation of the air with which it combines, also diminishes its conducting power. Thus alcohol, ether, and even aqueous vapor diffused in air render it a worse conductor than before. On the other hand, a condensation of air obviously encreases its conducting power. It also appears that many of the permanent gasses have their peculiar conducting power,* independent of extraneous vapour or dilatation.

Much remains to be done on the subject of the propagation of caloric through gaseous bodies, and the experiments necessary to pursue this inquiry are complex and difficult. At least four distinct calorific actions must be present in experiments of this nature, and the distinct power of each must be ascertained before any accurate conclusions can be drawn. One of these is the radiation of caloric from every heated surface when in contact with air; and as in all experiments vessels must be employed to confine the air examined, and thermometers to estimate the passage of heat, the radiations from these

solid bodies, and the propulsive energy belonging to the nature of their surfaces must be separately considered. Another circumstance to be considered is the density of the air examined, and its degree of moisture, both of which affect the passage of heat. A third is the motion of the particles of air produced, even in close vessels, by the partial application of heat, causing, as already explained, an ascending current over the heated body, of more or less velocity according to the difference of temperature between it and the surrounding medium. Besides these, it is probable that air has a proper *conducting* power distinct from its *conveying* power; that is, that even if its particles could be kept at rest on the partial application of heat, caloric would pass through its substance, as it does through a solid, and through every natural body hitherto known. But this distinction between the conducting and the conveying power will be more clearly pointed out in the following section.

Of the Conducting Power of Water.

In examining the propagation of caloric through water, radiation is totally out of the question, it having been fully proved that heat does not radiate through a dense liquid medium. Neither can the circumstance of rarity or density produced by external pressure sensibly affect an inelastic fluid; but only the change in specific gravity produced by the simple addition or abstraction of caloric. The enquiry is therefore much simpler than that of the passage of caloric through an aeriform medium, and is principally confined to these two objects, namely, the caloric which is *conveyed* through a mass of water by the ascent of the hotter particles, and the consequent descent of the colder ones; and the caloric which is *conducted* through water in any direction, and principally downwards, independent of the internal motions of its particles.

A number of facts of daily occurrence shew the almost impossibility of heating water or any other fluid effectually by applying heat on the surface, and the comparative ease with which it receives heat from the bottom. Thus it must often have occurred to chemists to observe in the process of distillation with a still and worm-pipe passing downwards through a tub of water in a spiral direction, that the upper part of the water which is in contact with the hottest portion of the pipe soon becomes scalding hot and continues so for a long time, whilst the lower part of the same water remains cold for many hours. But this principle was first more distinctly

* Leslie.

examined by Count Rumford, whose beautiful experiments on the propagation of heat in fluids^x rank with the most ingenious researches in natural philosophy.

It may be laid down as a general law, that when any portion of a fluid is heated above the common temperature of the contiguous mass, the hot particles immediately expand, and in so doing become specifically lighter than the rest; and therefore, if the heat is applied at bottom, the warmer fluid rises through the whole mass to the surface, giving off however on every side a portion of its excess of heat to the cooler liquid during its passage. But if the heat is applied at the surface, the upper part alone becomes heated, and being specifically the lightest it can only remain at the surface, and never comes in contact with the lower part of the mass, and consequently it cannot convey or carry caloric to it as in the former case. Many striking experiments, easily performed and perfectly convincing, prove that this is by much the principal method in which fluids become heated or cooled, so that for all general purposes it may be assumed to be impossible to propagate heat downwards or cold upwards in fluids without the assistance of mechanical agitation. Were this law absolute, it would follow that fluids are perfect *non-conductors* of caloric, since the conducting power implies the passage of caloric through successive particles or strata of bodies, and not the conveyance of caloric by the assistance of the movements of the heated bodies themselves.

Many are the experiments that shew the carrying power of heated fluids and the ascent of the heated particles. Thus if a quantity of hot water is poured into a jar of cold water through a long funnel touching the bottom of the vessel, the hot water will rise almost immediately to the top, encreasing the temperature of the whole mass in its passage. But if on the other hand cold water is poured down in the same manner into a vessel of hot water, it remains at the bottom, scarcely mixing with the hot, the surface of which will not have its temperature sensibly lowered for a considerable time.

The melting of ice under different circumstances of position is adduced by Count Rumford as a striking illustration of this principle. A piece of ice was fashioned so as to fill pretty closely about $3\frac{1}{2}$ inches in diameter of a tall cylindrical glass jar. Boiling water was first poured into the jar, and when nearly full the ice was dropped in, and melted *on the surface*

of the hot water in 2 minutes 58 seconds. The experiment was then repeated with this difference, that the ice was first fixed to *the bottom* of the jar by two thin slips of deal, a very small quantity of cold water poured on it to fill the interstices, and boiling water poured upon the whole. In this last experiment the circumstances were so different that in more than double the time in which the former ice had entirely disappeared, the latter shewed not the least disposition to melt. The temperature of the water being taken at different heights, during several intervals for two hours, it was found that in all the trials the bottom of the water (or the part immediately resting on the ice) was uniformly 40° ; but near the surface of the water, or seven inches above the ice, it was found at intervals of from 15 to 30 minutes, to have fallen to 160° , 149° , 131° , 117° , and at the end of two hours to $108\frac{1}{2}^{\circ}$. At three inches above the ice the temperatures at the same periods were respectively, 159° , 148° , 128° , 116° , and finally 106° . During this long period, at the end of which the surface of the hot water was still 108° , it was found that full half the ice remained unmelted, so that the thawing had been full eighty times slower than when the ice was at the surface; and as it would have continued to go on still slower, many hours would doubtless have elapsed before the whole was melted.

This leading experiment, without entering into the particulars, shews in a most striking manner the effect of situation in heating and cooling fluids, and fully proves that the equal diffusion of heat through fluids is chiefly owing to the carrying power, or the motions occasioned by the inferior specific gravity of the hotter compared with the colder part of the same fluid.

A similar experiment^y, but still more striking, is the actual boiling of water over the surface of ice for a length of time, without melting any considerable portion of it; and in a general way, no experiment that could be devised illustrates more remarkably the extreme difficulty of the passage of heat downwards through dense fluids. It is thus performed. Take a thin long glass jar or tube closed at one end, fill about three inches of its height with water, and freeze it into a very solid mass, fast adhering to the bottom of the jar. This is done by immersing the jar in a mixture of salt and snow, till the ice within is quite firm and hard. Then take it out, pour on the ice about two or three inches of ice-cold water, and wrap the outside of the jar with several folds of flannel to the level of

^x Essays.

^y Rumford's Essays.

the ice. Hold the jar by the end so covered at an angle of about 45° , and bring that part of it which is at the height of the surface of the water over the flame of a lamp or candle. When the surface begins to boil, slowly raise the tube so as to heat the lower part of the water, and thus, by avoiding to give a direct heat to the ice itself, the whole water will be seen to boil within a quarter of an inch of the ice. This ebullition may be continued several minutes before any sensible portion of the ice will be melted, except a small part of the upper portion, which is furthest from the flame, and on account of the inclination of the jar, rises above the level of the bottom of the water; so that after a time the surface of the ice is brought by melting to be nearly parallel with that of the water above.

If a jar be used, the heat of an Argand lamp will be required; and then a piece of wood or pasteboard should be interposed between the cold part of the jar and the glass chimney of the lamp.

It has been already mentioned that light flocculent substances inclosed in a stratum of air, very materially retard the passage of heat through it, probably by embarrassing those mutual motions of the hot and cold particles whereby the heat is conveyed from place to place. Count Rumford also found a similar effect to take place in *water* when mixed with substances either that gave it viscosity by dissolving in it, or that mechanically thickened it without actual solution. In the former case starch was employed, in the latter eider-down, as in the experiments on the conducting power of air. The general result of the experiments was the following: when pure water took only 597 seconds to heat from 32° to 200° , a *solution* of 192 grains of starch in 2276 parts of water, placed in precisely similar circumstances, took 1109 seconds to acquire the same degree of heat; and a *mixture* of 192 grains of eider-down diffused in the same quantity of water, took 949 seconds. Applying this fact to culinary purposes it accounts for the great length of time in which thick half-fluid substances retain their heat.

It was also found that encreasing the quantity of eider-down in a given stratum of air encreased the obstacle to the transmission of heat; and in like manner an additional quantity of eider-down in *water* encreased the difficulty with which it heated and cooled. For when pure water cooled 168° degrees in 597 seconds,

water with $\frac{1}{50}$ of its bulk of eider-down diffused through it took 763 seconds, and with $\frac{4}{50}$ it required as much as 949 seconds. In all these cases it was necessary to boil the eider-down with the water to detach the air that clings to it with great obstinacy.

Fluids therefore acquire and lose heat *principally* by the currents which always take place in them when partially heated, the warmer part ascending, and of course the colder part taking a contrary direction: and whatever impedes these motions will, proportionally to the degree of impediment, hinder the transmission of heat through the fluid.

This important and beautiful law is further illustrated by a most happy application made by Count Rumford, of a remarkable peculiarity that obtains in the specific gravity of water at the lower temperatures. It was first noticed by Mr. De Luc, and afterwards examined more particularly by Dr. Blagden, that when water at a high temperature is cooled, its density encreases gradually (like all other bodies when losing heat) to about the temperature of 40° , but, from this point to 32° , or as much below as it can be cooled without freezing, its density *actually diminishes*: so that just before it freezes it is considerably lighter than at 40° . No other fluid in nature is found to have this singular variation from the general law, and it is even wanting in strong saline solutions. Further experiments have fully confirmed this discovery, but with some little modification as to the precise point of extreme density, the alteration being extremely small for two or three degrees above and below 40° . Mr. Dalton² makes the maximum of density to be $42\frac{1}{2}$, and has added the curious fact that water expands equally at any equal number of degrees both above and below this point; so that the specific gravity of water at 32° , which is $10\frac{1}{2}^\circ$ below the maximum of density, is the same as that of water at 53° , which is $10\frac{1}{2}^\circ$ above the maximum.

Count Rumford applies this principle in the following way.² When hot water is poured upon ice frozen to the bottom of a jar, the water on the surface of the ice immediately is reduced to 32° ; but at this heat, being lighter than water a little warmer, it rises into the hotter mass above, whilst water at or near 40° descends upon the surface of the ice. This again, by the further melting of a fresh portion of the ice is reduced to 32° , when it loses part of its specific gravity and rises as the former

² Manch. Mem. vol. vi.

² Essays.

stratum did, sending down at the same time a fresh portion cooled to about 40° . Thus, whatever be the heat of the water at top of the jar, the ice itself is only acted on by water at about 40° , for only at this density can it sink through a stratum at 32° ; and therefore, as long as an atom of ice remains unmelted, this ascent of water at 32° and descent of water at 40° must take place.

Hence it is inferred that as much ice will be melted in a given time by superincumbent water at 40° , as by the same quantity of boiling water when at rest. In the experiment the undulation caused by the pouring in the water must have subsided before a fair comparison can be made, and then it was actually found after allowing for accidental irregularities, that full as much ice was melted in equal times by the cold as by the hot water, however paradoxical it may appear at first sight. Some powerful objections have been made to Count Rumford's opinion of the non-conducting power of water when at rest, taken absolutely; but there can be no doubt whatever that by far the greatest part of the transmission of caloric through fluids is made by the mutual currents of the hotter and colder part; and therefore that it is very slowly and with extreme difficulty that heat can be made to pass downwards through fluids, the single instance of water between 53° and 32° being excepted, which is only a confirmation of the fact.

Before we mention the objections to the opinion of the absolute non-conducting power of water, we cannot resist inserting the beautiful suggestion attempted by the same ingenious philosopher, of the final cause of this singular difference in the common law of regular condensation by cold, which occurs in water and no other fluid in nature, and only when approaching to within a few degrees of the freezing point. The direct operation of this law is to retard congelation, and to preserve a moderate temperature in all natural fresh waters during the severest cold, whereby it appears that the lives of a vast number of its subaqueous inhabitants are preserved, and an opportunity is afforded to man and other animals to procure in the coldest seasons this necessary element. The earth being always warmer in severe frost than the air, the cooling of the waters on the face of the earth must of course begin from its upper surface, which is exposed to the cold atmosphere. Therefore, when an intense cold air sweeps over a piece of water (a fresh-water lake for example) the surface as it cools becomes of

course of greater density and sinks down, giving place to the warmer stratum below to come to the surface. This in its turn becomes cooled and denser, and again subsides to give room to the next stratum. Thus the whole mass is first cooled to the point of extreme density, that is about 42° . But if this point were, like other fluids, the instant before freezing, the water would cool to 32° uniformly, after which (the external cold still continuing much below that point) the next step would probably be a sudden congelation of the whole body of ice-cold water. But as the density of water diminishes from 42° to the freezing point, no further sinking of the colder and rise of the warmer strata can take place, so that the upper stratum alone now receives the whole of the chilling action of the air, and there remains till it is converted into a crust of ice, the water beneath being all the while about 42° . When ice, it is still a worse conductor of heat than water at rest, and thus it long interposes between the cold of the air and the warm water beneath, besides that it protects it from the extreme chilling effect of sweeping winds; and it must be very slowly, stratum after stratum, that the process of congelation can proceed downwards through a considerable depth of water.

On the other hand the same circumstance contributes to hasten the thawing of ice in a warm atmosphere. If this peculiarity did not occur, and if water at rest were an absolute non-conductor of heat, it would be impossible that a mass of ice should ever thaw except by the slow and circuitous passage of heat upwards through the earth. For the first effect of the warm air would be to thaw a thin stratum on the surface of the ice, which if it were (as in other liquids) lighter than the cold surface that touched the ice, would only remain at rest on the spot in which it was thawed, and would transmit no heat whatever to the ice below. Whereas, as it actually happens, the thawed surface with the first additional heat that it acquires, becomes *heavier* instead of lighter, and of course sinks to the surface of the yet unthawed ice, imparts to it its excess of heat, and again, becoming lighter thereby, returns to the air, to acquire a fresh portion of heat which it again carries down. Thus a constant circulation of alternately warmer and colder water goes on above the ice till it is all thawed, and also proceeds further downwards till the temperature of the whole water rises to about 42° ; after which the usual law of expansion by heat is resumed, for all the higher temperatures.

Experiments were also made by Count Rumford to determine whether heat could be propagated downwards through oil and mercury. These fluids being uniformly dilated with any increase of heat from any temperature at which they remain uncongealed, no such precautions were necessary as when water near the freezing point was used. The apparatus used was a cake of ice frozen to the bottom of a jar, with a projecting point or nipple at the surface: this was entirely covered with the oil or the mercury, and a solid cylinder of iron heated in boiling water was let down through the oil or mercury to within $\frac{2}{10}$ of an inch of the nipple of ice. Though the heated iron was so near it, no sensible quantity of ice was melted; and as all the motions produced in the fluid by the unequal heating took place a little above the level of the ice, it shewed that the communication of heat through the fluids could only be made by means of heated currents, and therefore could not properly be *conducted* through them.

Though these very curious experiments shew incontestibly that the heating and cooling of fluids is *chiefly* carried on by means of the currents into which they are thrown when heat is partially communicated, there is very strong evidence from subsequent experiments that this is not the only way in which caloric is propagated through them; or in other words, that fluids are not absolute non-conductors of heat, though they are certainly very bad conductors.

The actual motion of the currents of differently heated particles in any mass of fluid, has been attempted to be shewn in different methods. One of them, which was adopted by Count Rumford, is to suspend in the fluid minute particles of any opaque solid substance reduced to powder, which is not chemically acted on by the fluid, and whose specific gravity is so nearly the same as that of the fluid in which it is immersed that it will rise or fall merely with the currents. Amber is a little heavier than pure water, but if a small quantity of carbonate of potash or any other salt be added, it may easily be brought to the requisite density, and no chemical action takes place between the two.

When a glass jar thus filled, and the fluid cold, is immersed in another large jar containing very hot water, the particles of amber which before were at rest in every part of the water, immediately begin to fall into regular currents, and all that are near the sides of the jar, being

the nearest to the hot water on the outside, begin instantly to *ascend* with great rapidity and regularity, whilst of course a *descending* current is formed in the centre of the jar. This continues, but with diminishing velocity, till the whole of the water in the inner jar is brought nearly to the same temperature, when the particles again remain at rest. If the process is reversed, and the jar now hot is immersed in cold water, or even simply exposed to cold air, the currents now run exactly in a contrary direction, the outer circumference cooling first, and forming a *descending* stream, whilst the inner cylinder of water of course *ascends*; and these currents again continue till the temperature is equalized through the whole jar.

This most entertaining experiment, though it corresponds very well in *form* with what actually takes place in the water itself, differs essentially in *degree*; for the rapidity of the motion of the amber particles is much beyond what would be required to account for the actual rate of heating or cooling in the water itself. Therefore, much of the effect is owing to the expansion or condensation of the amber itself, rendering it lighter or heavier than the liquor in which it is immersed; and these respective currents of the floating particles must be considered only as an imitation, or rather an exaggerated representation of what actually takes place in the water. This was very satisfactorily proved by Dr. Thompson,^b who repeated the experiment nearly in the same way, but with the ingenious contrivance of colouring blue the lower half of the liquor, and leaving the upper part uncoloured. On applying heat at the bottom, the amber particles were readily set in motion, and they rose not only to the top of the blue part, but through this into the colourless portion, *without being accompanied by any of the coloured solution*, which of course would have been readily visible. By continuing the heat for ten minutes, the two liquors did indeed become uniformly mixed, but the motion of the amber particles began almost immediately on applying heat, and were fully established through the whole of both liquors before the colour had spread upwards in any sensible degree.

Hence it follows, that the only satisfactory way of rendering the currents of the water itself visible, is by tinging a part, and then the gradual admixture of colour can only be brought about by the actual admixture of the different particles of the fluid itself.

To prove the real conducting power of water,

or the passage of heat through it, unaccompanied by corresponding currents, very satisfactory experiments have been made by Dr. Thompson,^c Mr. Dalton,^d and Mr. Murray.^e All of them proceed on the general principle of endeavouring to communicate caloric in a direction contrary to that of the currents which are excited in partially heated fluids. In many of them a vessel was filled with water unequally heated, in which, during the process of cooling, no alteration of specific gravity could make any current; and as notwithstanding, the temperature of the water in the different parts of the vessel gradually became equal, it was inferred that water (or whatever was the fluid used) possessed a real conducting power.

To fulfil these conditions, either a hot liquid must be put upon a stratum of the same liquid cold, or a hot liquid of greater specific gravity must be put at the bottom, and a cold liquid of less gravity at the top. In either case there can be no current from one to the other. The particulars of these and other similar experiments need not be related; in all there was a gradual equalization of the temperature, but not till a considerable time had elapsed.

Some nicety of management is required in pouring one liquor down a tall jar on the surface of another liquor without mixing the two in any material degree. To do it in the most expeditious and best way, a thin wooden float should first be let down on the lower liquid and the stream of the upper liquid directed upon it, which will break the force of the current, and keep the two so much separated, that if only one be coloured, the line of distinction will be obvious, and pretty well defined.

As caloric cannot radiate through dense fluids, if it passes through them without the assistance of currents (that is, without being conveyed), it must be conducted through, unless it is communicated through the sides of the vessel that must be used to make the experiment. This has generally been of glass, which is itself a bad conductor of heat; but still it cannot be denied that where one part of the same vessel confines a hot and the other part a cold fluid, the varying quantities of heat absorbed by the vessel itself must after a time be equalized by the conducting power which solids indisputably possess, and a consequent equalization of temperature must sooner or later take place in their contents by this cause alone, even were no other to operate. In those of the above experiments that lasted many minutes, even as much as one or two

hours, a very large deduction must be made for the conducting power of the vessel, but a beautiful experiment of Mr. Murray's, made in a vessel of ice (and therefore a perfect non-conductor for all temperatures above 32°, whilst it continued to be ice), shews a conducting power in fluids independent of the vessel containing them.^f Some of the particulars may be mentioned. A quantity of water was frozen in a tin mould, so as to form a hollow cylinder 3 inches in diameter, 3½ in depth, and of 1½ thickness of ice. A thermometer was introduced into it horizontally, at the depth of one inch, the bulb being in the axis of the cylinder, and was frozen in. A quantity of almond oil was then poured into the ice vessel, so as to cover the bulb of the thermometer one quarter of an inch. A small flat-bottomed iron cup, holding two ounces by measure, was then suspended over the oil, so as merely to touch the surface, without dipping to any sensible depth. This cup was then filled with boiling water; so that the heat passing through its bottom would directly touch only the surface of the oil, which was a quarter of an inch above the thermometer bulb. Thus situated, if the thermometer rose, it shewed that the heat must have been fairly conducted downwards through this depth of the ice-cold oil, for the sides of the vessel being ice could not have conveyed it, nor would any heated currents reach sensibly lower than the bottom of the heated cup. The mercury rose from 32° to 32¼ in a minute and a half, and to 37½ in five minutes, after which it remained stationary for a while and then gradually sunk again to 32°. The effect of the heat had excavated a portion of the top of the ice vessel, and even as low as the bottom of the thermometer bulb. The same experiment was repeated, substituting mercury to the almond oil, and the iron cup was now allowed to float on the surface of the mercury, but still at a sensible distance from the thermometer. This rose instantly on the pouring the boiling water into the cup, from 32° to 36°, and again slowly sunk to the freezing point.

Each of these experiments were repeated with different heights of fluid over the thermometer, and in all, some rise of the thermometer was observable, though when covered with one inch of mercury it amounted to no more than three-fourths of a degree.

Having thus related the principal facts concerning the passage of heat through solids, liquids, and gases, in its radiated and conducted states,

^c Ph. Jour. vol. 4.

^d Manch. Mem. vol. 4.

^e Ph. Jour. 8vo. vol. 1.

^f Ph. Jour.

before its chemical combinations are noticed, some further observations may be added concerning the expansion, which invariably attends an encrease of the quantity of caloric in every substance in nature, in the circumstances above mentioned.

Of Expansion.

It is by the expansion which fluids undergo when heated that the encrease or diminution in the quantity of sensible caloric in any body is usually measured. This is done by the THERMOMETER. How far this instrument applies will be mentioned in the next section when treating of combined caloric.

The expansion of several fluids has been measured with considerable accuracy, and the peculiarity that takes place in the expansion of water at low temperatures has been noticed. This singular fact, first accurately ascertained by Mr. De Luc, and afterwards by Dr. Blagden, has been further illustrated by Mr. Dalton,^f who has shewn that water expands equally at equal degrees above or below its maximum of density. The experiments were made by filling a thermometer tube with water, and immersing it in water of known temperatures, or in different freezing mixtures, using a good mercurial thermometer as a standard. It has been mentioned that the maximum of density is somewhere about 40° to 43° , but the difference of expansion for two or three degrees above or below 41° , is so small as scarcely to be cognizable. Mr. Dalton estimates the maximum at $42\frac{1}{2}^{\circ}$, and finds that water inclosed in a thermometer bulb, may be cooled not only to about 21° (as Dr. Blagden had discovered) but even as low as 5° or 6° without freezing. When actually cooling below $42\frac{1}{2}^{\circ}$, the water *rises* on the scale, and exactly in correspondence with equal distances above $42\frac{1}{2}^{\circ}$, so that for example when the liquor stands at 63° of the scale, it is impossible to tell by mere inspection, whether it is actually 63° (20° above the maximum of density) or $22\frac{1}{2}^{\circ}$ (20° below the maximum).

A great difference takes place in the expansion of different liquids by equal quantities of heat. This is not apparently connected with their specific gravity, but as Dr. Thompson^g suggests it seems to depend on the degree at which the liquid boils, those liquids having the greatest expansion whose boiling points are the lowest. Thus mercury expands with a given temperature much less than water, whose boiling point is much lower; and water, again, expands less

than alcohol, which boils at a lower temperature. So that as a general rule it may be laid down that the expansibility of liquids is in some proportion inversely as their boiling points.

Another important circumstance concerning the expansion of liquids is that they all expand more with equal additions of heat at the higher than the lower temperatures. This variation is not very uniform, nor is the law of the encrease in all cases very obvious. In water, however, the encrease at the higher temperatures nearly corresponds with the squares of the natural numbers. Thus, if the original bulk of water be assumed as 10000, the expansion at $82\frac{1}{2}^{\circ}$ may be taken at the square of 6 or (36), and that of every ten degrees above $82\frac{1}{2}^{\circ}$ will be successively nearly as follows: at $92\frac{1}{2}^{\circ}=7^2$ (49): at $102\frac{1}{2}^{\circ}=8^2$ (64): at $112\frac{1}{2}^{\circ}=9^2$ (81): and so on, according to the squares of the natural numbers. Owing to the peculiarity in the expansion of water, just mentioned, the same rate of expansion will also apply to the descending scale of heat, at like distances from $42\frac{1}{2}^{\circ}$, as long as it can be preserved unfrozen. M. De Luc has clearly pointed out how this encreasing expansion of fluids in the higher temperatures throws an unavoidable error on the common construction of the thermometer, the scale of which always supposes equal expansion, and of which the degrees divide equal spaces in the tube. Thus if, as is commonly done, two distant points of the scale are first marked (that of freezing and boiling water for example) and the scale is then divided into 180° equal spaces, it is obvious that 90° degrees from the freezing point, or half this space, will not exactly indicate half the entire expansion of the mercury from these two points, but the lower half of the scale will be too large, and the upper too small. The real medium of temperature would be at 118.85° of the common scale, or 86.85 degrees above 32° , the freezing point.

By experiments on other fluids, M. De Luc found this difference to be greater, as will be seen by the following table. The scale of Reaumur's thermometer was used, which divides the interval between freezing and boiling water into 80 degrees. The mean number is therefore, by the scale, 40° , but the real mean of expansion expressed in the first column is, in all the substances examined, lower than this point. The second and third column of numbers expresses the proportion between the higher and lower parts of the scale of expansion.

^f Manch. Mem. vol. v. pt. 2.

^g Elements of Chemistry.

Mercury - - - -	38.6	15 : 14
Olive and linseed oil -	37.8	15 : 13.4
Oil of camomile - -	37.2	15 : 13
Water saturated with salt	34.9	15 : 11.6
Alcohol - - - - -	33.7	15 : 10.9

Mercury is however the most uniform in its expansion for equal quantities of heat, of any fluid known, and doubtless chiefly for the reason already mentioned, namely, that its boiling point is higher than other fluids. Hence its peculiar advantage in the construction of *thermometers*, under which article the expansion of fluids will be further noticed.

The expansion of solids is much less than that of fluids or gasses, and is so small that it cannot be accurately observed without a micrometer, and mechanical contrivances of unequal levers for successively multiplying the effect. These machines are called *pyrometers*, and that invented by Mr. Smeaton is esteemed one of the most perfect and accurate. A pyrometer of platina has been attempted by Guyton,^h to measure the higher degrees of heat. It consists of a bar of this metal enclosed in a groove of highly burnt clay, and with a complicated index at one end, whereby an expansion amounting to not more than about a five-thousandth of an inch is clearly ascertained. The expansion of solids appears to be pretty equable for equal quantities of heat.

Gasses and gasiform vapors expand very largely by heat, much more so than solids or fluids. The dilatation of air is shewn very strikingly by the *manometer* or *air thermometer* as it is sometimes termed, which consists simply in confining air in a bulb of glass by a column of coloured liquor that fills the tube communicating with it. On changing the temperature of the air in the bulb in any degree, however slight, the consequent expansion or contraction is immediately seen by a considerable fall or rise of the coloured liquor. But as the extreme elasticity of air causes it also to be enlarged or contracted by a diminished or increased pressure of the atmosphere, a barometrical correction on this account is always requisite in manometrical experiments.

In all chemical experiments on which the quantity of gasses is to be estimated, the temperature at the time of measuring them must be taken into the account, and proper corrections made when this exceeds or falls short of the standard of comparison. Thus 1000 parts of common air at 32°, expand to 1058 at 60°, and to 1104 at 82°.

A great number of experiments have been made by different persons to ascertain the expansion of air by heat, as it is a subject intimately connected with many physical observations, and in particular with all barometrical experiments. When the natural atmosphere is examined, the quantity of water which it holds in solution most essentially modifies the expansibility, and in low temperatures much of the aqueous vapour which it held in solution is destroyed and separated in a liquid form. This vapour may be almost entirely separated from air by several chemical means, such as putting the air in contact with sulphuric acid, or solid potash, which have so strong an affinity with water as to extract it from the air that holds it in solution.

From late experiments by Mr. Dalton in England, and M. Gay Lussac in France, both of which bear the mark of great accuracy, and correspond very closely with each other, the very important and convenient inference is deduced, that all gasses expand equally by equal degrees of heat, provided they be free from condensable vapour at the temperatures at which the experiments are made. Hence a table of the expansion of any one gas will apply to all the rest.

Gasses also appear to expand pretty equally for equal degrees of heat, and not in an encreasing ratio, like water or other dense fluids. Indeed the thermometer indicates a contrary rate of expansion, that is, one that regularly diminishes as the temperature encreases; but Mr. Dalton very acutely suggests that this anomaly is in all probability only owing to the inaccuracy of the thermometer itself, which from its being divided into equal degrees, is not a perfectly accurate measure of equal expansions in the higher temperatures, for the reason already mentioned; and the effect of the inaccuracy in this instrument is to give to a really equal expansion the appearance of a diminishing ratio. The experiments on the expansion of aeriform bodies will be given under the article Gas.

The only apparent exceptions to the general law of the expansion of all bodies by heat are, the regular contraction of baked clay in encreasing degrees of heat, on the one hand, and on the other the great expansion which many liquids undergo in the act of congelation. With regard to the former it will be further explained under the article PYROMETER (*Wedgerwood's*.)

The degree of expansion which water undergoes by congelation is very considerable, and its force is one of the most (if not the most)

prodigious of any of the spontaneous actions of natural bodies. If a block of ice swimming in water may be estimated to rise about one-sixth of its bulk above the surface of the water, five parts of water by weight would occupy about the same bulk as six of ice. The force of expansion was long known to be such as to burst any vessel in which water was set to freeze, if filled full; and by Major Williams's experiments at Quebec, this force was found in intense cold to be able to burst very large pieces of ordnance. For the particulars of these, see the article FREEZING.

Some of the metals expand on their congelation or fixation. Iron is of this kind, and hence the unmelted metal will swim on the surface of the melted; whereas silver, lead, and many others, contract on cooling, and therefore sink in a melted mass of the same metal. The chief cause of this expansion in water, metal, and in an infinite number of saline and other solutions, when passing from the fluid to the solid state, appears without doubt to depend on the new arrangement of particles produced by the *crystallization*, but the subject is still very obscure. However it does not in the least invalidate the general law of expansion by heat, since these same substances when solid are expanded and contracted as before by gain or loss of caloric.

OF COMBINED OR LATENT CALORIC.

In the two preceding sections of radiated and conducted caloric, heat has been considered only in that state of freedom or of loose combination in which it exists in its passage through solids, fluids, and gasses. This is properly the *caloric of temperature*, or that whereby the equilibrium of temperature is constantly kept up in all bodies in nature; and, as has been amply shewn, no substance, whatever difficulty caloric finds in permeating it, can absolutely detain it or prevent its passage. Perhaps the term of *tension* of caloric, adopted by Prevost, Piçtet, and some other writers, will express with more exactness the idea which may be formed of this state of caloric. This is measured by the thermometer, that is by a very small mass of matter (generally mercury) extremely permeable by heat, which, when put in contact with the substance examined, readily acquires the same tension of heat, without lessening the actual quantity in any sensible proportion by what it absorbs, and furnishes a comparative scale of temperature by the expansion which it undergoes. That the thermometer does not measure the actual quantity of caloric is evident from the circumstance that it gives the same indication immersed in a

large as in a small mass of matter. Thus it is obvious that two pounds of boiling water contain twice as much caloric as one pound of boiling water, but the thermometer in both stands at the same degree. Neither does this instrument give the comparative quantities of caloric in the same bulk of different substances. If separate vessels containing water, mercury, oil, brine, &c. are all immersed in water kept a sufficient time at the boiling point, after a greater or less time they will all acquire a temperature a few degrees below 212° ; but this does not in the least prove that they contain equal quantities of heat, and the circumstance of the unequal times required in each to arrive at this point is a strong argument against the quantities of caloric being equal.

The analogy given by M. Piçtet between humectation and heating, will further illustrate, as far as it holds, the nature of thermometrical indication. Suppose at the same instant a pound of dried sponge, a pound of blotting paper, and a pound of some porous wood be plunged into a basin of water. After a short time the substance that receives water the easiest (suppose the blotting paper) will be thoroughly soaked; in a little longer time the sponge will be in the same condition, and after a longer time, the wood. When taken out of the water they will all be thoroughly wet, and if a hygrometer (which is a machine that shews the degree of moisture of the air by expansion or contraction of hair, catgut, or any other hygrometrical substance) could be applied to them all, it would only shew in each the same and the extreme degree of humidity, but would give no indication whatever of the actual quantity of water which each contained. In this therefore it resembles the thermometer applied to heated bodies. Let the three substances be now thoroughly dried in a very warm situation, and the hygrometer would only mark in them the term of extreme dryness, and not the quantities of water which they had respectively lost, which would be the most in the sponge, the next in the paper, and the least in the wood. But after this thorough exsiccation, if the three substances were strongly heated in close vessels, they would yield a further quantity of water, also in unequal proportions, as the wood would now furnish the greatest; and this may bear an analogy to the caloric of combination, which is no more indicated by the thermometer than the combined water would be by the hygrometer.

Let a quantity of ice cooled down to 20° be put in a vessel and gently heated by a small

lamp that burns steadily and equally. If a thermometer be immersed in the ice it will gradually rise from 20° to 32° . The ice will now melt slowly, and during the whole time of melting, the thermometer touching it will remain stationary, notwithstanding the accession of heat continues as before. Therefore, during the melting of ice, a quantity of heat insensible to the thermometer is absorbed; and if the heat is communicated from the bottom, the water already produced is prevented from acquiring a higher temperature till every particle of the ice is thawed. Hence it follows that a quantity of heat is necessary to be added to ice before it can be converted into water, and which does not raise the thermometric temperature. Let the heating continue as before, and the water produced by the thawing of the ice now again shews an encrease of sensible heat, and the thermometer continues to rise gradually through the whole scale up to 212° , in the latter part of which time the water begins to send forth steam, and at last to boil violently. Now again a second and permanent stop is put to the rise of the thermometer, for though the addition of heat received from the lamp continues as before, the thermometer never rises higher than 212° , but instead, a large quantity of aqueous vapour flies off, also at the heat of 212° , till every drop of the water is evaporated. Now if in the first case all the heat received during the thawing of the ice (at which time the thermometer was stationary) was absorbed by the water in order to enable it to assume the liquid form, it follows, by parity of reasoning, that all the heat received during the boiling (the thermometer being now as before stationary) is employed in the conversion of water into aqueous vapour. In both cases heat is received, and as it is the common effect of heat to raise the thermometric temperature, the absence of this effect can only be accounted for by supposing it necessary for the existence of aqueous vapour that it should be composed of a greater quantity of heat than water, and water more than ice.

Upon these fundamental experiments, Dr. Black formed that beautiful system of the nature of heat which carried with it irresistible conviction wherever it spread, which is now (with some modifications) universally adopted, and has been extended to the full explanation of an infinite number of the most important phenomena in natural philosophy. The particular experiments and inferences from them must be examined more minutely. The leading

circumstances or heads of inquiry suggested and illustrated by Dr. Black's discovery, are the following:

1. The absorption of caloric from the surrounding bodies by liquids in the process of liquefaction, and by vapours in the process of evaporation, being necessary to the constitution of liquids and vapours. Caloric in this state is termed by Dr. Black *Latent Heat*, because it is as it were concealed in the substance of the liquid or vapour; and is opposed to *Free or Sensible Heat*. Latent heat has been also termed *Combined caloric*, which is perhaps a better term, as it expresses (what is probably the fact) that a chemical combination takes place; as (for example) between ice and caloric to constitute the fluid, water.

2. The expulsion of caloric from liquids during congelation, and from vapours during their condensation into liquids. In this case the caloric which was before in a latent state now becomes free, and therefore sensible to the thermometer. This expulsion of caloric is of course a necessary inference from the fact of its absorption in opposite circumstances, and the proofs of its taking place are equally decided.

3. The proportional quantity of caloric necessary to be added to any substance to raise it to a given thermometrical temperature. This comparison refers both to the different states of the same body (as ice, water, and vapour) or to different bodies indiscriminately, the quantities of the substances being always equal. As these experiments are proportional to each other, they are for convenience all referred to a common standard, which in this case, as in that of specific gravities, is water. This is called the *Specific Caloric* of bodies, or as Dr. Black terms it the *Capacity of Bodies for Heat*. Thus if it takes three times as much heat to raise a certain quantity of water 10 degrees, as the same quantity of mercury, the specific caloric of water, or its capacity for heat, is said to be three times as great: or if that of water be called 1. that of mercury will be $\frac{1}{3}$.

4. The absolute quantity of caloric contained in any substance. We have no reason to think that we have ever by natural or artificial cold deprived any substance of all the caloric which it contains; but many ingenious attempts have been made to estimate the point of actual privation of heat, or the real zero in different bodies, and thence to compute the absolute quantity which is contained in substances at given temperatures. As heat cannot be weighed or measured, some measure of effect must be

adopted to express absolute quantities of it. This has been done either by the thermometer, or by the thawing of a given weight of ice.

Of Liquefaction and Congelation.

The opposite states of *Liquefaction* and *Congelation* may be conveniently described under the same head, as the circumstances attending the one will illustrate the other, after which the similarly contrasted phenomena of evaporation and condensation of vapour will be noticed.

During the liquefaction of any substance by mere heat, it has been already mentioned that a large quantity of heat is absorbed by the melting substance which is essential to the constitution of the state of liquidity, and does not raise the thermometrical temperature. Consequently if a solid substance, cold, and the same substance in a liquid state, and hot, be mixed in known proportions, the temperature after mixture will not be the proportional mean of the temperature of each, as would be the case if both were liquid, but will fall far short of it: a great portion of the heat of the hotter body being taken up with melting the colder solid body before its temperature can be raised a single degree. Thus, equal parts of water at 32° , and water at 212° , will on mixture give the temperature of 122° , or the arithmetical mean between these two numbers; but equal parts of ice at 32° and water at 212° , will give only a temperature of about 52° , the greater portion of the heat of the water being first employed in thawing the ice before any rise of temperature whatever can take place in the mixture.

Dr. Black's original experiments¹ on the absorption of heat during the process of liquefaction may here be shortly mentioned, on account of their elegant simplicity, as they served as ground-works of his beautiful system.

Two equal globular glass vessels were filled, the one with five ounces of water, which was afterwards frozen by surrounding it with salt and snow, and the other with water simply cooled down to 33° . That which contained the ice was allowed to remain in a warmer air till the ice just began to melt, at which time its temperature was as nearly as possible 32° or 33° . The two vessels were then simply suspended from a wire frame set in the middle of a large room without a fire or any notable draught of air, and of the average temperature of 47° . The vessels were therefore in every respect under similar circumstances of temperature within and without, and with similar contents, excepting that one contained ice and the other water. The

progress of heating was then noted. In that which held the water the thermometer rose in half an hour to 40° ; but in the other it took no less than 10 hours and a half before all the ice was melted, and the contents had reached to 40° . Consequently the rate of heating was 21 times slower in the ice-vessel than in that which held the cold water; but the actual heat received by the former was nearly uniform the whole time, and therefore it required about 21 times as much heat to bring ice to the state of water and to raise it to 40° , as to raise ice-cold water to the same point. Or, to express it by another form, if the water had continued to receive as great an influx of heat as the ice, during the whole 21 half-hours, its temperature would of course have been raised 21 times as much as during the single half-hour, and as this was 7 degrees, the whole would have been $21 \times 7 = 147$ degrees. The difference between the gain of temperature in the ice and the water with equal accessions of heat, is about 140 degrees; and therefore 140° is the expression of that quantity of thermometric temperature which is destroyed, or made *latent*, by the separate operation of the liquefaction of ice, the actual quantities of matter in the comparison being equal.

This calculation was confirmed by the experiment of melting ice in hot water, and comparing the temperature of the mixture with what it would have been had ice-cold water been used instead of ice. When quantities of water of unequal temperature are mixed together, the heat of the mixture is the exact mean of the difference of temperatures and the respective quantities. In Dr. Black's experiment, 119 parts of ice at 32° were melted by 135 parts of water at 190° , to which must be added the heat communicated by the hot vessel, which he estimated as equal to 8 more of the water, making in the whole 143 parts. Now the gain of temperature produced by adding 119 parts of water at 32° , to 143 parts of water at 190° , would have been 86 degrees above 32° , or 118° of the scale; (being found by multiplying the difference of temperature into the weight of the hotter water, and dividing by the sum of the weights of both, for $\frac{158 \times 158}{262} = 86$). But the temperature resulting from the melted ice and hot water was only 21 degrees above 32, or 53° of the scale. Therefore a quantity of heat had disappeared, which would have raised the whole mass (equivalent to 262 parts of water) 65 degrees, being the difference

¹ Lectures on the Elements of Chemistry.

between 86° and 21° . But the same quantity of caloric which would raise 262 parts of water 65 degrees, would raise 119 parts 143 degrees; and the weight of the ice alone being 119, it follows that during its liquefaction, heat is absorbed equivalent to 143 degrees of temperature, and which can in no other way be accounted for than by supposing it intimately combined with the water as it becomes liquid, and essential to its state of liquidity.

The near correspondence of this experiment with the former, the one giving 140 and the other 143 degrees, is a convincing proof of the truth of the general inference drawn from them; for this does not depend on minute observation where an inaccuracy of a degree or two or any inequality of mixture will defeat the object of the experiment, but upon a large, palpable, and striking difference which must be obvious to every observer.

To save the trouble of any calculation of proportion, this beautiful experiment may be made with equal or with aliquot weights of ice and hot water. So if a lump of ice is dropped into an equal weight of water heated to 200° , 140 degrees of heat may be first subtracted from the hot water to counterbalance the liquefaction of the ice, and the real effect will therefore be the same as if water at 60° and ice-cold water at 32° were mixed in equal proportions, and accordingly the heat of the mixture will be the mean of 32° and 60° , or 46° . If the hot water be twice the weight of the ice, only half the quantity (or 70 degrees) must be subtracted, and so in proportion.

The general law deduced from these experiments, therefore, is that *liquefaction* always demands the addition of a great quantity of caloric beyond what the thermometer will indicate, and hence a substance during this change absorbs caloric powerfully from all the surrounding bodies, and leaves them *comparatively cold*. Liquefaction is therefore a frigorific process, and this discovery explains the production of cold and the theory of freezing mixtures in a great variety of instances. Many of these will be mentioned after the opposite process of congelation has been described. Liquefaction at the higher temperatures is often termed *fusion*, thus we rather say the *fusion* than the *liquefaction* of metals, or even of wax, spermaceti, &c. But in all these cases an absorption of caloric also takes place, which is shewn by preventing the substances from acquiring a higher temperature than their point of fusion, as long as a particle remains unmelted; or by reducing the tem-

perature of the melted substance immediately to this point, when above it, if a piece of the unmelted body is thrown in. Thus a ladle full of lead cannot be heated red-hot till all the metal is melted; and a quantity of red-hot melted lead is directly cooled to the point of fusion by the addition of solid lead.

Since caloric is *absorbed* during liquefaction, it follows that it must be *given out* during congelation; or, that not only the free thermometrical heat will be lowered to the congelating point, but that the latent caloric combined with the liquid will also be expelled before congelation can take place. Similar experiments to some of those already described, will therefore apply (changing the circumstances) to the phenomena of congelation. Thus if a vessel of warm water is exposed to a very cold medium, the temperature is rapidly cooled down to the freezing point, after which the water begins to congeal. If kept in the same situation, caloric is abstracted as before, but the thermometrical heat now remains nearly the same, till all the water has lost its whole stock of combined caloric necessary to fluidity, and is totally converted into ice, and it is not till after this period that the temperature begins again to sink as before. Also if ice, however cold (suppose at 0°) be added to water at 32° , the effect is to congeal a portion of water, and the caloric given out by the water in the process raises the temperature of the ice to 32° . Therefore ice swimming in water can never have a lower temperature than 32° , and this point is so invariable as to furnish an excellent standard for the graduation of thermometers.

Congelation therefore is as much a *heating* process to the surrounding bodies, as liquefaction was shewn to be a *cooling* process. That is, the reduction of the temperature of any substance to any given point below its freezing point is much retarded, if in the process it be necessary to convert a liquid body into a solid by the abstraction of caloric: for ice at 32° can much sooner be cooled 10 degrees, than water at 32° , the ice having only to surrender its free uncombined caloric, but the water having, in addition to this, to give up its latent caloric of fluidity.

The heating power of congelation with respect to the surrounding bodies, is generally to be shewn only by its retarding the rate of the cooling which these bodies would experience without the influence of this process. In a few instances however it is more strikingly shewn by an actual *rise* of a thermometer immersed in fluids at the moment of their congelation. The

following experiment of Fahrenheit shews it. If water (and better just after having boiled for a quarter of an hour) be put into a deep vessel immersed in salt and snow, or any other powerful freezing mixture, and allowed to remain perfectly at rest and without any wind playing over its surface, it may readily be cooled to about 8 or 10 degrees below 32° , or even more without freezing. If now the vessel be slightly shaken or jarred, or especially if an atom of ice be dropped in, almost the whole water suddenly shoots into fine crystals of ice, and the temperature slowly rises to 32° , the freezing point. The reason of this considerable rise of the actual temperature is the suddenness of the congelation. In common circumstances the formation of ice in freezing water is so gradual, that the latent heat extricated from the water by congelation is immediately diffused through the surrounding medium, and does not sensibly affect the thermometer: but when the whole is cooled so low as 20° or 22° , the whole of the latent heat is ready to quit the water at the instant that congelation begins in any one point, and then becomes sensible to the thermometer.

The crystallization of those salts that are more soluble in hot than in cold water is a true congelation, and the extrication of caloric from them in the moment of crystallization equally takes place. None of them shews this phenomenon more beautifully than sulphat of soda (Glauber's salt); but some little management is requisite to ensure its cooling down below its congelating point, and remaining fluid. The following method seldom fails. Take any quantity of this salt, a pound for example, and heat it in a clean iron ladle on a clear brisk fire. The salt speedily melts in its own water of crystallization, and boils violently. Continue the heat till all the water is expelled, and a white dry saline mass remains. Then add sufficient water to it (without removing it from the ladle) to redissolve by boiling almost, but not quite, the whole of the salt. This liquor, which is a perfectly saturated solution, should be poured, while still quite hot, into a thin glass phial, and immediately corked quite close, or better, covered with wet bladder, so as to exclude all the external air from the solution. Set this by in a quiet place without shaking, and it will now cool to the temperature of the air, remaining perfectly fluid. On opening the cork and letting in the external air, the liquor immediately begins to congeal on its upper surface, and the congelation spreads downwards in a few seconds, like a dense white cloud; after which it is so entirely solidified

that on inverting the bottle not a drop of liquor falls out. If it should not immediately congeal on opening the cork, a slight shake, or dropping in an atom of the same salt will begin the process, after which it never fails to spread through the whole in a few seconds. It may be added that the same solution will answer repeatedly any number of times, and after the first time there is no occasion previously to calcine the salt, but merely to heat the phial containing it till it is totally liquefied. During the sudden congelation, a quantity of heat is given out sufficient to make the outside of the phial sensibly warm to the hands, and to raise the thermometer 20 or 25 degrees. The cause of this encrease of temperature can be no other than the escape of the latent heat of the solution caused by its change from a fluid to a solid state.

Numberless facts might be adduced in illustration of what has been mentioned concerning the evolution of sensible heat during congelation, and its absorption during liquefaction. As a general rule it may be remarked that whatever melts the most rapidly is likely to produce the greatest cold, and whatever congeals the most rapidly will (*ceteris paribus*) produce the most heat. However this is also regulated by the relative affinity for caloric which different substances may have. The mode in which artificial cold is produced by saline solutions partly belongs to this part of the subject.

In all these cases a sudden liquefaction of the salt employed takes place, which therefore requires a proportional supply of caloric from all the adjacent bodies to furnish it. Thus if salt and snow (one of the most powerful of the freezing compounds) are mixed together, they melt with great rapidity (the snow simply by the absorption of heat, the salt by the united power of caloric and water), and every substance immersed in the mixture is robbed of a large portion of its caloric to supply the demand. The quantity of heat absorbed, or the measure of the frigorific power, always bears a proportion to the cold required to congeal the mixture. Thus the freezing point of the brine is at least 32° degrees lower than that of water, or the zero of the common scale, and hence we may infer that a much larger quantity of latent caloric is contained in brine than in water at equal temperatures, since so much more powerful a cold is required to congeal the former than the latter. The utmost limit of the frigorific power of these mixtures, therefore, is their point of congelation; for the same reason that prevents melting

ice from producing a greater cold than 32° during its liquefaction, will prevent brine from producing a lower temperature than about 0° , these being respectively the freezing points of the two substances. In like manner the cold occasioned by salt and snow continues nearly at the same intensity during the whole time of melting; as also takes place with melting ice: and if brine be slowly cooled a few degrees below 0° , its freezing point, as soon as any portion of the salt separates in a solid form, the temperature rises to that point; just as the temperature of over-cooled water rises to 32° on sudden congelation.^k

The particular freezing mixtures, with the best mode of their application, will be described under the article FREEZING.

Of Vapour and Evaporation.

When water is heated in any open vessel, the thermometrical temperature rises gradually, at the same time that aqueous vapour soon begins visibly to form at the surface. This encreases till the water has risen to its boiling point, which is about 212° of the common thermometer; at which time the whole is thrown into violent agitation, and the formation of steam is rapid and copious. The temperature now no longer rises, but remains, both in the water and in the steam, at the same point, till the whole is evaporated or boiled away.

The two principal circumstances to be attended to in this process, which is every day before our eyes, are, the expansion which the water undergoes by being converted into steam; and the uniformity of temperature maintained notwithstanding the constant accession of heat during the boiling.

The invariable relation between the quantity of heated vapour formed, and the quantity of heat carried off in a state insensible to the thermometer, led Dr. Black to apply his beautiful theory of latent heat to the vaporization of liquids as well as the liquefaction of solids, and has furnished the most irrefragable arguments for its truth.

The expansion of water when converted into steam was long known to be very great, and many experiments were made, before Dr. Black's inquiries, to ascertain the exact amount. More accurate trials, by Dr. Black, and his eminent pupil and friend, Mr. James Watt, fix the expansion at 1800 times the bulk of the water. As vapour, while such, is a rare, invisible and highly elastic fluid, the temperature and pressure must be taken into account in this estimate.

The former is 212° , or the highest heat that unconfined watery vapour can assume, and the latter is the common pressure of the atmosphere. Hence we may reckon generally that water kept fully boiling in open vessels is converted into 1800 times its bulk of boiling-hot vapour.

The combination of a great quantity of caloric with water in the formation of steam, was determined by Dr. Black in a similar manner as the combination of caloric with ice, in order to produce liquefaction. Water was heated as uniformly as possible in a tin vessel to boiling, and the time required for this was noted. The same heat was then continued till the whole was evaporated, and the time taken up by the process was noted. Now since on the one hand the accession of heat was constant, it was readily computed how high the temperature would have been, supposing the rise to have gone on above 212° in the same ratio as below it; and, on the other, as the temperature of the steam was not raised, it was inferred that all the accession of caloric from 212° was essential to the very state and constitution of vapour at that temperature. This quantity Dr. Black estimates from the average of many of his first experiments to be about 810 degrees: that is to say, that the same quantity of caloric which is required totally to evaporate boiling water at 212° , would be sufficient to raise the water 810 degrees above the boiling point, or to 1022 if it had remained in its liquid state.

On the other hand, it will follow that when steam is condensed again into water, it will give out all the latent caloric which was necessary to its vaporous state, which being now set free from its combination, will readily be diffused among all the adjacent bodies, and raise their temperature as much more than an equal weight of boiling water will do, as the latent caloric of steam exceeds that of water. This furnishes another method of estimating the latent caloric of watery vapour, and somewhat more accurate than the former, since in the experiment of boiling water some of it evaporates before it arrives at 212° , and it is necessary to assume as a datum that the rate of thermometrical heat in this fluid would be the same above the boiling point (were there no evaporation) as below it.

The most convenient method of heating water by means of steam, is to imitate the process of common distillation; that is, to heat water in a close vessel in order to generate the aqueous vapour, and to cause the vapour to be condensed in a metallic pipe passing in a spiral form through

^k Black.

a tub, or any other vessel that contains the cold water, which is to receive the heat given out by the steam during its condensation. Here the vapour does not indeed actually come in contact with the water, but its latent caloric is given out and passes through the metallic pipe immersed in the water. In perfect accuracy the quantity of caloric required to raise the temperature of the metallic pipe should also be estimated, but here (as in the experiments on congelation) this minuteness of observation is not in the least necessary to establish the general law of latent caloric, the thermometrical difference on which it is founded being so great and palpable that very considerable errors are not felt. The experiments of Dr. Black and of Mr. Watt on the condensation of a given weight of steam in a known quantity of water, give about 950° for the latent heat of steam or aqueous vapour at the boiling point: that is to say, that boiling water renders latent during its total conversion into steam a quantity of caloric, which otherwise would have raised it to 950 degrees. This enormous quantity of heat given out by steam was long observed during the common process of distillation, and remained unaccounted for till the theory of latent heat occurred to Dr. Black. Of late the use of steam has been most advantageously extended to the heating of large masses of water in breweries, dye-houses, bleacheries, &c. In these the steam is produced in a strong iron boiler, with no other outlet than the pipe or pipes which convey off the steam when generated. One pipe passes to each cistern of cold water, and heats it, not as in distillation by merely passing through, but by discharging the steam into the body of the water, being generally admitted from below. A few minutes of a strong jet of steam will bring a large cistern of cold water to a scalding heat, and a further quantity will soon raise it to boiling.

The facts that have been advanced concerning the latent heat of steam (and the same applies to all condensible vapours) are finely illustrated by the instrument called from the inventor *Papin's digester*. Its intention is forcibly to confine heated water by mechanical pressure, and thus to prevent the formation of steam, whereby the water is compelled to assume a much higher temperature than 212° . It consists merely of a very strong iron or copper boiler, whose lid fits on perfectly tight, and is kept down by thick screws. This is half filled with water, the lid closed, and set on a fire. The water soon rises to the boiling point, and

so much steam is formed as will fill the vacant space above. By continuing the heat, the water being prevented by the confinement from forming more than a limited quantity of steam, now rapidly acquires a much greater heat than 212° , and by this is enabled to dissolve bone, horn, muscle, and a great many other substances on which unconfined boiling water has but very trifling action. To prevent the great hazard of a dangerous explosion from the prodigiously accumulating expansive force of the steam within, the digester is furnished with a very tight valve, kept down by a considerable pressure, but which will fly open before the vessel is in any danger of bursting. The circumstance that strongly illustrates the theory of latent heat is the following. When the water within the digester has risen to an excessive heat (suppose 400° , which is 188 degrees above the natural boiling point) if the valve is now opened, a quantity of steam rushes out with extreme violence, and the heat of the remaining water within almost immediately sinks to about 212° . Thus we find that the formation of a certain quantity of steam from over-heated water, carries off with it a great proportion of the sensible heat of the water, and both steam and water fall to a much lower temperature than before, which can only be explained satisfactorily by the hypothesis of the large proportion of heat rendered latent in the steam at the moment of its formation.

The conversion of water into aqueous vapour is therefore a *cooling* process with regard to all the contiguous bodies, for the same reason that the liquefaction of ice or other solid bodies produces the same effect: and on the contrary, the condensation of a vapor into a liquid, and of a liquid into a solid, are for the same reason *heating* processes. This general law applies not only to water, but to all known substances whose form alters by different doses of caloric.

The cold produced by the evaporation of fluids at low temperatures furnishes many interesting and very illustrative experiments. Alcohol and ether are fluids that boil at a much lower temperature than water, and they, as well as water and many other fluids, readily evaporate at a much lower heat than their boiling point, even at the common heat of the atmosphere, and thus any substance moistened with any evaporable fluid is rendered much colder, or is robbed of much caloric, by the spontaneous evaporation of the fluid. This is much assisted by a brisk wind, or any artificial renewal of the air on the moistened surface. Thus if a wet

cloth is spread out in a keen wind at a temperature a little above freezing, the water by rapidly evaporating soon cools the damp cloth below the freezing point, and makes it hard and stiff with the formation of ice within its pores. But the cold produced by evaporating ether is still more striking. A little of this singularly evaporable fluid poured on the back of the hand flies off immediately, and leaves the hand excessively cold. If a thermometer bulb is kept constantly damp with ether, the mercury sinks rapidly many degrees below 32° , and if the evaporation is assisted by agitation, or by a very strong draught of air, the mercury may be lowered to a much greater cold than any natural to this climate, except in very rare instances. This is readily performed in a few minutes with a small delicate mercurial thermometer: if the bulb be wrapped round with a little tow, soaked by once dipping it in ether, and blown upon with a hand bellows held a little distance off, it will then sink as low as 0° , or even a degree or two lower.

The evaporation of all fluids is regulated as much by the density of the air with which they are in contact as by the degree in which they are heated, and in a direct ratio to each other; so that the denser the atmosphere pressing on them, and the higher is the evaporable or the boiling heat required. Hence it follows that by diminishing the pressure, liquids will boil at a much lower temperature than their natural point of ebullition. Thus it is found that at the top of high mountains liquids boil much sooner than at the bottom. Saussure found that water boiled at the top of Mont Blanc at 187° Fahr. instead of 212° , and other liquids in proportion. The same effect is produced artificially by inclosing the liquid, already heated to a certain point, under the receiver of an air-pump and exhausting the air. If water scalding hot be put in this situation, a few strokes of the pump will make it boil vehemently, but this lasts only a short time, on account of the cold produced by the evaporation, which lowers the temperature immediately. A further exhaustion renews the ebullition, a less heat being now required, till the cold of the evaporation has again lowered the temperature; and thus the alternate boiling and cooling may be renewed for a considerable time.

Ether, which evaporates so readily under the common atmospherical pressure and temperature, and which boils at about 102° in the open air, is brought to ebullition at a low heat, simply by removing the pressure, and the cold thus gene-

rated (as already mentioned) is very intense. This furnishes a very pretty experiment. Put a little ether (well rectified by washing with water) into a thin vessel of glass or metal, inclosed in another vessel, with a little water interposed between the two. Set the whole under the receiver of an air-pump, and exhaust the air briskly. The ether will very soon begin to boil vehemently and rapidly evaporate, and the cold thereby produced will in a few minutes freeze the water on the outside of the inner vessel, and may be taken out as a coating of ice adhering to it. As some of the ether spurts out during the ebullition, it should be prevented from mixing with the water on the outside, which would retard its congelation.

Advantage is taken of the cold produced by evaporation to manufacture ice in the tropical climates, where the natural temperature is never so low as 32° . At Benares, in the East Indies, very porous earthen vessels are employed, and the water constantly and slowly oozing through them produces by its evaporation sufficient cold in the night to form a thin coating of ice. (See the article FREEZING.) In Spain, and many of the Mediterranean countries, water is kept constantly cool by being kept in porous earthen jars, called in Spain *Alcarazzas*, and in Egypt *Balaffes*, which furnish a constant evaporation from their surface. Bottles of wine and other liquors are cooled by being set in these jars with water interposed.

The evaporation constantly going on from the surface of animal bodies in the form of insensible or sensible perspiration, is the principal cooling process to check the accumulation of heat in the system, and it is well known by the feelings of every one how much this evaporation is increased (in the healthy body) by external temperature, exercise, and other circumstances that encrease the production of heat. The remarkable experiments of Sir C. Blagden, Dr. Fordyce, and others, in an excessively heated room, shew that the living animal can exist in a *dry* heat even above 212° , that of boiling water, and that the internal temperature remains notwithstanding nearly at its natural point of about 98° , the enormous excess of external temperature being counteracted by the profuse perspiration. (See the article RESPIRATION.)

The constitution of some of the permanent gases, or those that remain in a gaseous state in the temperature of the atmosphere, shews the combination of latent caloric necessary to the gaseous state, though not in so marked a manner as the *vapours*. Several of the gases

may readily be condensed into the liquid state by union with water, and some by union with each other even pass into solids. In both these cases sensible heat should be given out to the surrounding bodies, as in the condensation of steam, and this actually happens, though by no means in such quantity. Thus when sulphuric acid is added to common salt, muriatic acid gas is given out in great abundance, and in close dry vessels it scarcely exceeds the temperature of the air at the time, or if surrounded with ice may readily be cooled to 32° . But if a large stream of this gas be passed into water, it is immediately condensed, uniting with this fluid into liquid muriatic acid, and during the process so much heat is given out as to raise the liquid even as high as 160° ; so that in preparing it, it is necessary to keep the vessel artificially cool by wet cloths or ice. The caloric given out is that which was latent in the gas during its aeriform state. Also if muriatic gas and ammoniacal gas, both of the common temperature, be mixed together, they instantly unite, forming white clouds of solid muriated ammonia, and by losing their gaseous form so much heat is given out as to make the vessel very sensibly warm to the hand. It must be mentioned however that the quantity of caloric given out by the permanent gases during their union with solids or liquids, is in no degree proportioned to the ease with which they are condensed, and is in many cases so small as to be scarcely if at all perceptible by the thermometer.

Of Specific and Absolute Caloric.

When equal quantities of the same substance, but of different temperatures, are mixed together, the temperature after mixture is very exactly the arithmetical mean, or the middle point between the highest and lowest. Thus when a pound of water at 50° is mixed with a pound of water at 90° , the mixture will be 70° (allowing for the effect of the vessel itself in which they are contained, and taking precautions to avoid any sensible error from the temperature of the surrounding air.) Now, though the absolute quantity of heat contained in each pound of water is unknown, it is obvious that the water at 90° contains as much heat as the water at 50° ; and in addition, as much as is requisite to raise it 40 degrees of a certain thermometrical scale. After mixture the two pounds therefore contain twice as much heat as will raise one pound of water to 50° , and besides, as much as will raise one pound 40 degrees. The first portion, being permanent, may be put

out of the question, and therefore, only considering that which forms the excess between the two, it appears that as much caloric as will raise one pound of water 40 degrees will raise two pounds 20 degrees. Now all the experiments on the distribution of caloric shew that two bodies unequally heated when mixed together will sooner or later acquire an equal temperature, the cooler body gaining precisely what the hotter body loses; and as in the above example the temperature of 70° is the middle point between 50° and 90° , the hotter and the cooler, it appears that equal quantities of heat are required to raise equal weights of water the same number of degrees of temperature, whatever be the actual temperature before the caloric is added. This inference is confirmed by experiments made at various parts of the range from 32° to 212° .

But if equal weights of *heterogeneous* substances are employed, the result is widely different, the temperature after mixture being never the mean of the thermometrical difference, but sometimes above, sometimes below it. Thus if a pound of water at 40° be mixed with a pound of mercury at 69° , the temperature of the mixture will not be 54.5° , the arithmetical mean, but only 41° . Consequently the mercury has lost 28 degrees of heat, all of which has been absorbed by the water, and has only raised it 1 degree, and therefore it may be stated that it requires twenty-eight times as much caloric to raise water to a given temperature as to raise an equal weight of mercury to the same point. This power of retaining caloric or proportion between the quantity of heat received and the consequent rise of temperature, was first termed by Dr. Black, *Capacity for Heat*, an expression which is sufficiently intelligible though not perfectly accurate. It has been adopted by Dr. Irvine and Dr. Crawford,¹ who were among the first to elucidate this most important subject, and to bring to regular demonstration what was only suggested by Black. Thus in the instance above mentioned, water is said to have twenty-eight times the capacity for caloric that mercury has, because it will hold, or requires, twenty-eight times as much heat, to produce an equal change of temperature. The term *Specific Caloric* is better devised to express the same thing, that is to say, the proportional quantities of caloric requisite to raise equal weights of matter the same number of degrees of thermometrical temperature. This is exactly the same as the respective capacities

¹ Experiments on Animal Heat, 2d edition.

for heat, and the numbers that express the capacities are inversely as the degrees of temperature to which the several substances are raised by equal quantities of heat. Thus in the instance above given, equal quantities of heat will raise mercury 28 degrees and water 1, and therefore the specific caloric or capacity of caloric of the two liquids is inversely as 28 : 1, or when water is reckoned as unity, mercury will be $\frac{1}{28}$. As all these numbers are comparative with each other, and do not express any absolute quantity of heat, it is necessary and convenient to assume a common standard of comparison, and here, as in the case of specific gravity, water is the standard fixed upon, and assumed to be unity. The substances compared are also generally estimated by equal *weights* and not *measures*, but the former may be readily converted into the latter by multiplying into their specific gravities. Thus as mercury is (in round numbers) 14 times as heavy as the same bulk of water, equal bulks of the two liquids would give 14 pounds of mercury to one pound of water, and if these are mixed at the respective temperatures of 69 and 40, the mixture will be about 49 $\frac{1}{2}$, making the respective capacities of water and mercury as 1 to $\frac{1}{2}$ with equal bulks.

Two data must be assumed in this calculation, the one, that equal degrees of the thermometer will measure equal increments of heat; and the other, that the specific caloric of bodies remains the same in any temperature, provided the form is unchanged. It has been already mentioned that the expansion of mercury is nearly, though not rigorously, uniform in all the common temperatures at which experiments are made, that is for a considerable distance above and below the points of freezing and boiling water: and the very accurate experiments of Crawford shew that much reliance may be placed on the general position that the capacities for heat are equal in the same substance at every temperature, while the form remains the same.

The general formula for estimating the specific caloric of bodies from the temperature resulting from the mixture of two substances at unequal temperatures, whatever be their respective quantities, is the following, but it is convenient that one of these substances be water, as it is the standard of comparison, and its specific caloric is therefore reckoned as = 1. Multiply the weight of water by the difference between its temperature before mixture, and that of the mixture itself. Also multiply the weight of the

other substance by the difference between its temperature and that of the mixture. Divide the first product by the second, and the quotient will express the specific caloric of the other substance, that of water being 1. For example, suppose 20 ounces of water at 105° be mixed with 12 ounces of spermaceti oil at 40°, and the temperature after mixture be 90°. Then multiply 20 by 15 (the difference between 105° and 90°) = 300: and multiply 12 by 50 (the difference between 40° and 90°) = 600: and 300 divided by 600 will give $\frac{1}{2}$ or .5, which is the specific caloric of the oil, compared to that of water, which is 1. The same rule holds when the water is the colder of the two.

The above rule gives the specific caloric of equal *weights* of the two substances: to make it apply to equal bulks the specific caloric of the substance compared with water must be multiplied by its specific gravity. Thus in the above instance if the specific gravity of the oil be .92, the specific heat for equal *bulks* will only be .46, for this conversion into equal bulks is in fact the same as diminishing the weight, when oil is the subject of experiment. Therefore when the comparison of equal *weights* is converted into that of equal *measures* or *bulks*, those substances that are *lighter* than water will have the number expressing the specific caloric *diminished*, and those that are *heavier* will have it *increased*.

Many precautions are required in these experiments to ensure tolerable accuracy, and the effect of the vessel itself must be estimated separately by previous experiment.^m

The specific caloric of solids was ascertained very early in this enquiry by Wilcke of Sweden, and published in the Stockholm Academy Transactions for 1772. By ingenious calculationsⁿ he found first the quantities of water required to produce a similar effect with that of the solid employed, whence the specific caloric was afterwards deduced.

Mr. Leslie suggests^o an elegant and simple mode of determining the specific caloric of bodies from observing their relative times of cooling a certain number of degrees comparatively with water in similar circumstances. A very thin glass globe, with a narrow neck to receive the bulb of a fine thermometer, is a convenient vessel for this purpose. First fill it with hot water, and observe the time required to cool a certain number of degrees, estimating always from the temperature of the room, or better a given number of degrees above it, and not from

^m Crawford.

ⁿ Thompson's Chemistry, vol. i. where they are accommodated to Fahrenheit's thermometer.

^o Enquiry on Heat, p. 340, 548.

any fixed point on the scale: take, for example, the thirty degrees included between the fortieth and the tenth degree above the heat of the room. Let this be a standard and reduce it to unity; then fill the glass with any other liquid, and the time of its losing the same thirty degrees will express in *direct* proportion the specific caloric. These results only give the specific caloric of equal bulks, to reduce them to equivalent expressions of equal weights *divide* them by the specific gravities. Thus Mr. Leslie found that a very thin glass ball of $2\frac{1}{2}$ inches diameter filled with water, cooled a certain number of degrees of temperature in 70 minutes, and when filled with oil it cooled to the same point in 32 minutes. Therefore, reducing water to 1., the specific caloric of oil of equal bulk will be .46. This divided by .92, the specific gravity of oil, will give .5 for the specific caloric of equal weights. When solids are to be examined they must be broken into fragments, put into the glass globe, and filled up with water, and the specific effect of the water must be separately estimated and deducted from that which belongs to the solid, by rules of which the reader will find many examples in Crawford's treatise. In using this apparatus with perfect accuracy, the separate effect of the glass should also be accounted for, and care should be taken in the cooling to avoid currents of air, or any other circumstance that might derange the uniformity of the process.

The capacity of gasses and vapours differs respectively, according to the nature of the gas; and also in each individual gas, it varies largely according to its density, or the pressure to which it is exposed. Every aeriform substance being a highly elastic fluid, is readily dilated or condensed by diminishing or adding to its pressure, and it is found that sudden dilatation produces cold in the surrounding bodies, and sudden condensation gives out heat. Consequently the capacity for caloric must increase by expansion, and a similar effect, but much less in degree, takes place by this process, as in the prodigious expansion of water into steam, or ether into etherized vapour; that is, the absorption of caloric from all the adjacent parts, in order to supply the demand produced by the sudden increase of capacity for caloric in the vapour.

It has long been observed that if a thermometer be enclosed in a small receiver and the air briskly exhausted, the mercury rapidly sinks a few degrees, after which it slowly rises to the common temperature of the room. When the

air is again let into the receiver, the thermometer again suddenly rises a few degrees above the common temperature, after which it slowly settles again to the same point, shewing the opposite effect of condensation in diminishing the capacity for caloric, and consequently expelling a part of the heat of the air in a sensible form. An artificial condensation of the common air produces a similar effect. This is performed for experiment in a *condenser*, which is a strong air-tight piston, by working which an additional quantity of air may be thrown into any confined vessel. A thermometer enclosed in it rises several degrees during the condensation. The same extrication of heat from condensed air is also shewn in working the air-gun, which soon makes the barrel very sensibly hot to the hands; and the blast of condensed air when discharged on the bulb of a thermometer sinks it a few degrees, owing to the cold produced by the sudden expansion. This striking occurrence takes place on a vast scale at the fountain of Hiero, at the mines of Chemnitz, in Hungary. A part of the machinery for working these mines is a perpendicular column of water 260 feet high, which presses on a quantity of air enclosed in a tight reservoir. The air is consequently condensed to an enormous degree by this height of water, which is equal to 8 or 9 atmospheres, and when a pipe communicating with this reservoir of condensed air is suddenly opened, it rushes out with extreme velocity, instantly expands, and in so doing it absorbs so much caloric as to precipitate the moisture it contained, in a shower of very white compact snow, or rather hail, which may readily be gathered on a hat held in the blast. The force of this is so great that the workman who holds the hat is obliged to lean his back against the wall to retain it in its position. ^p If the cock of the pipe is only partly opened, the snow is still more compact.

Another striking experiment, the direct reverse of the foregoing (that is the sudden heating of bodies contiguous to air in the act of condensation) is given in the *Bulletin des Sciences*. ^q If the air be very rapidly compressed in the ball of an air-gun, so great a quantity of heat is disengaged from it at the first stroke as actually to set fire to a morsel of *amadou* (or fungus match with nitre) enclosed in the ball. If the body of the pump be terminated with a moveable end formed by a piece of steel screwed on, and furnished in its centre with a glass lens, a ray of vivid light will be perceived on the first stroke of the piston.

^p Journ. Phys. tom. 48. p. 166.

^q Phil. Jour. vol. ix. p. 302.

The capacity of the vapour of condensible fluids appears to be still more encreased by expansion than that of the permanent gasses, and consequently the vaporization of liquids requires more heat when the vapour exists in an expanded than in a condensed state. This circumstance throws a great obstacle to the plan of distillation in vacuo economically considered, which has been proposed by some ingenious persons, and which at first sight would appear to promise many advantages. It is undoubted that a liquid will evaporate and boil in vacuo at a much lower temperature than in the free air, but the constitution of vapour in this situation requires a much greater quantity of combined caloric than when under external pressure; and consequently, the advantage gained by boiling at a lower temperature is counterbalanced by the larger quantity of fuel required to furnish the additional dose of combined or latent caloric demanded by the vapour when uncompressed. The experiments of Mr. Watt first proved the truth of this position.^r A small still was half filled with water and very closely luted to the worm-pipe of the cooler, which was also furnished with an air-tight stop-cock at the lower end through which the distilled liquor drops in common distillation. To empty the whole apparatus of air, the water in the still was made to boil violently and the steam to pass through the whole of the worm-pipe uncondensed, no water being put into the tub of the cooler. This expelled nearly all the common air contained in the vessels, and the stop-cock was immediately closed and the fire removed. The steam then condensed, and nearly a perfect vacuum was left in the vessels. The cooler was then filled with cold water and the still very slowly heated, the stop-cock at the bottom remaining all the while closed. The water distilled perfectly well in this vacuum at a very low temperature, and the heat of the steam was found to be only 100° instead of 212° as in common boiling, so that the vessels scarcely felt hot to the hand. But by estimating the heat acquired by the water of the cooling-tub during the condensation of the steam, it was found to be so much more than what would have been produced by common steam, that by calculations similar to those already mentioned, the latent heat of this uncompressed steam must be reckoned at 1048, instead of about 840, the heat of common steam. With a more perfect vacuum, Mr. Watt found that water would distil very well at 70°, but then the latent heat of its vapour approaches to 1300.

^r Black's Lectures, p. 188.

From the result of some experiments devised with great ingenuity, Mr. Dalton^s concludes that the heat and cold produced by the mechanical rarefaction and condensation of air is in fact much more than is indicated by the thermometer (which rises or falls only a very few degrees), on account of the small size of the vessels used in the experiments, and the comparative suddenness with which the equilibrium is restored from without. The rapidity of the change of the thermometer in these cases compared to the time required for an equal change, when the instrument rises or falls a few degrees in the open air, seems to confirm the conjecture of a great excess of heat or cold acting suddenly, and as speedily counteracted; and, among others, the following experiments appear to prove it. A small graduated glass tube, 10 inches long, and with a bore only $\frac{1}{15}$ of an inch diameter, was closed at the lower end, and a short column of mercury introduced a little way down the upper or open end. The bore of the tube being so small, the mercury remained where it was introduced without dropping down, thus separating from the external air that portion of air which was contained in the part of the tube below it, but by its rise or fall it would readily indicate the expansion or contraction of this confined portion of air. The tube was introduced under a glass receiver of an air pump, to which a condenser was also attached. The receiver therefore would contain two very unequal portions of air, but under the same circumstances of pressure, the smaller portion being that very minute quantity intercepted in the glass tube between the mercury and the closed extremity, and the larger portion being all the rest of the contents of the receiver. Now, as the smaller portion is closely contiguous to a thick wall of glass, and is only $\frac{1}{15}$ of an inch in diameter, all the changes of temperature within it, arising from rarefaction or condensation altering its capacity for caloric, may fairly be supposed to be almost instantly counteracted, and the equilibrium restored by the contiguous parts; but in the larger portion, which includes by far the greater part of a large receiver, a very sensible time must elapse before the equilibrium can be entirely restored. This time, the author reckons at about 10 seconds.

In the first experiment, the density of the whole air within the receiver was doubled by a condenser, and of course the small column of mercury was pressed down in the small tube, communicating to the air beneath the same

^s Manch. Mem. vol v.

pressure as that above. After a while the cock was suddenly opened, the excess of air rushed out, and the mercury again rose in a few seconds to its former level, and the cock was immediately closed. The pressure from the condensation was therefore removed, but the cold thereby produced still remained in the air of the receiver, though, for the reasons above mentioned, it was counteracted in the air of the tube by the heat it would instantly absorb from the glass itself. The column of mercury then began again to sink down the tube (the cock being all the while closed) and became stationary when it had shortened of the length of the aerial column by $\frac{1}{10}$. This was obviously owing to the expansion and pressure of the air in the body of the receiver by the restoration of the equilibrium of heat through the sides of the vessel, which acted in the same manner as the first condenser, and accordingly, when the cock was again opened, air rushed out of the receiver, and the mercury finally rose to its first level. The next experiment was the reverse of the former. The column of mercury was first let down to within one-fourth of the length of the tube from the sealed end: three-fourths of the air was then exhausted from the receiver (which was known by the air in the tube expanding till the mercury reached the top), the stop-cock was opened for a few instants till the mercury had subsided to its former level; it was then shut, and the mercury now rose in the tube for five or ten seconds to more than $\frac{1}{10}$ of its original height, owing to the cooling of the air confined within the body of the receiver, and which had acquired its heat by the sudden condensation on opening the stop-cock. Accordingly on again opening the stop-cock, air rushed in, and the mercury subsided to its former level. In each experiment a change of about $\frac{1}{10}$ of the bulk of the air of the tube was produced after the equilibrium of mechanical pressure had been restored; and consequently the whole of this is to be attributed to the operation of the increased or diminished heat; and as a change of 50 degrees of heat is known to produce this quantity of effect on air, it is to be inferred that this change, above or below the common temperature, actually takes place in the receiver in the above experiments. The condensation of aqueous vapour is very considerable in the first experiment, where condensed air is suddenly rarefied, the sudden cold causing this watery precipitation; but this does not contribute to the production of the cold, but has a contrary effect, as indeed must always

happen when a vapour is converted to a liquid form.

It has been already mentioned that in the estimation of the specific caloric of bodies they are always supposed to retain the same form, that is, solid, liquid, or gaseous, for it is only then that it can be assumed that equal increments of heat produce equal changes of thermometrical temperature. But a knowledge of the specific heat of any substance will give a ready method of calculating the latent heat, or the quantity of caloric absorbed during the successive passage from solidity to the state of liquid or vapour. Several experiments on the latent heat of melted metals are given by Dr. Irvine, junr. * Bismuth will furnish an example. This metal when just in fusion, or when a portion of the melted mass has begun to congeal, raises the thermometer to 476° . A quantity of it perfectly fluid, and amounting to 1555 grains, was poured into a vessel holding 2236 grains of water at 62° . The heat of the mixture was 86.25° , therefore the water had gained 24.25 degrees, and the bismuth had lost 389.75 degrees: and hence 1555 grains of water (that is, equal in weight to the bismuth) would have gained 34 degrees. Now the specific caloric of solid bismuth compared with water is previously known to be .042, so that the same quantity of heat that will raise water $.042^{\circ}$ will raise bismuth 1° , and consequently what will raise water 34° will raise bismuth 809.5° . But the bismuth actually lost only 389.75° of temperature, and consequently the difference between 389.45° and 809.5° , or 419.75° , will express the quantity of latent heat in the melted metal, or that which is lost when melted bismuth at 476° is changed into solid bismuth at the same temperature. In actual experiment however several precautions are required and corrections necessary, both for the quantity of water dissipated in steam when a melted metal is poured into it, and for the small particles of metal which may be carried off or oxydated, and also for the heat acquired by the vessel in which the experiment is made. Besides it is well ascertained that the mercurial thermometer becomes very sensibly inaccurate as a measure of equal accessions of heat when the temperature is very high.

To obviate the objections that arise in some cases from the use of thermometer as a measure of heat, a very ingenious application was made by Messrs. La Place and Lavoisier, of another direct effect of heat, in order to estimate respective quantities of this subtle, imponderous

* Ph. Jour. vol. ix.

matter. The thermometer measures heat by the expansion of the fluid employed (which is generally mercury); the *Calorimeter* of La Place and Lavoisier measures it by the quantity of ice at 32° , which it melts under similar circumstances. This method appears at first sight to be capable of very great accuracy, for ice beginning to melt is invariably at 32° , and the quantity of water produced must, if accurately collected, be an exact measure of relative quantities of caloric. The calorimeter is a hollow cylindrical vessel made of tinned iron, and containing three distinct concentric cavities separated from each other by circular partitions of the same material. The object intended is to place the heated body in contact with or contiguous to ice, so insulated that no heat can get to it but that of the subject of experiment. The inner cavity is intended for the heated body; the middle one contains the ice to be melted by it, and for readier communication the partition is perforated all over; and the outer cavity also contains ice, which is intended to detain the heat of the external air, and prevent it from reaching the ice of the middle cavity, whilst the partition between the two keeps entirely separate the melted water of each. A lid ingeniously contrived with corresponding partitions shuts over the whole. At the bottom are two pipes, one communicating with the outer, the other with the middle cavity. The water from the melted ice drains off through them, that from the outer cavity is not noted, but that from the middle is carefully collected and weighed. Some smaller precautions are required, and an extension of the apparatus to particular purposes,^a which need not here be enumerated.

As the quantities indicated by the calorimeter are only proportional, some standard of comparison must be fixed upon, and this the inventors have determined to be the quantity of caloric necessary to melt a pound of ice, which therefore is called 1. This is equivalent to the effect of a pound of water at 135° above 32° , or 167° , which will also melt a pound of ice. The example given by Lavoisier of the application of the instrument to other bodies may be here inserted. A quantity of iron rolled in narrow slips, and weighing 7.7070319 pounds, was heated in boiling water to 207.5° , or 175.5 above 32° , and introduced within the inner cavity of the calorimeter. In cooling to 32° it melted 1.109795 pounds of water. Hence it is found by direct proportion that if 175.5 degrees

of caloric above 32° will melt 1.109795 pounds of ice :: 135 degrees above 32° would melt 0.85384 pounds. And 135° above 32° , or 167° , is the temperature to which a pound of water must be raised to melt a pound of ice. Therefore by equal losses of temperature, 1 pound of water will melt 1 pound of ice, and 7.7070319 pounds of iron will melt 0.85384 pounds of ice; or (dividing 0.85384 by 7.7070319) 1 pound of iron will melt .1109 pound of ice. Therefore the quantity of caloric given out by iron, is to that given out by water, at equal differences of temperature, as .1109 to 1.

In measuring temperatures near the utmost limit of the scale of the mercurial thermometer and upwards, the calorimeter may certainly be made a valuable instrument; but it appears from some experiments by the late Mr. Wedgwood,^v that it is scarcely possible to separate with accuracy the melted water from the ice remaining in the middle cavity of the instrument, and even, as it should seem, a portion of the thawed ice again freezes, so as to throw much uncertainty on this method of estimating relative quantities of caloric.

The attempts that have been made by several very accurate experimentalists to weigh caloric need not be particularly described. Fordyce, Lavoisier, Rumford, and Higgins, have each instituted experiments with great care, but the results of none prove unexceptionably that any weight can be attributed to caloric, or that any substance within the reach of human instruments weighs less when cold than when hot, no other change having taken place than the mere loss of caloric. In balances that are adjusted with extreme accuracy, the vicinity of a hot body to one end of the scale beam will readily expand it enough to destroy for a time the equilibration; and if this cause of error is avoided by allowing a considerable time to elapse between the weighing of the substance before and after the loss of heat (it being at the temperature of the atmosphere in each case) a slight change may probably have taken place in the weight of the air, amounting to a sensible difference of the barometer, which will cause an additional difficulty in these delicate researches. Even if some ascertainable weight could be found to a considerable quantity of caloric, it is obvious that the balance could never be practically employed as a substitute to the thermometer.

Of Absolute Caloric.

The specific caloric of a body has been shewn

^a Mem. de l'Acad. for 1780, or Lavoisier's Chemistry, p. 421.

^v Phil. Trans. vol. 74.

to be the proportional quantity of caloric necessary to raise its temperature any given number of degrees, compared with that required to raise an equal weight of any other body, and especially water, which is the standard generally agreed upon. The proportions between these respective quantities are assumed to be the same at any actual temperature, provided the respective states remain unchanged, that is, provided solids remain solid; liquids, liquid; and gasses, gaseous form. For example, it requires twice as much caloric to raise tin to any given point as it does to raise lead to the same, or, expressed in the proportions to water, the specific caloric of tin, according to Dr. Crawford, is .070, and of lead is .035, and these proportions are supposed to be the same from the lowest possible temperature to any degree short of the melting point of tin, which is the most easily fusible of the two. Consequently, if they could be put in a situation to be deprived of all their caloric of temperature, the tin would lose exactly double the quantity that the lead would do, and therefore at all equal temperatures the absolute quantity of heat contained in tin is double that of the lead.

This leads to the enquiry into the *real zero*, or the point of *absolute cold* measured by an equidifferential thermometer, for though such a thermometrical measurement is practically impossible, the scale may be hypothetically extended indefinitely to any distance below the actual zero. It may be premised that there is no reason to suppose that any degree of cold, natural or artificial, ever observed, has approached the term of absolute privation of temperature. Formerly the zero of Fahrenheit was supposed to be this point, but an actual cold of at least 40° lower is now procurable without much difficulty in the congelation of mercury, and by particular means a cold of much greater intensity may be produced, though the measurement below this becomes very uncertain, for want of an unexceptionable liquid for the thermometer when mercury becomes useless. Even in the most intense cold ever produced, pure alcohol remains fluid, and the permanent gasses retain their gaseous form, but from analogy we may reasonably suppose that alcohol owes its fluidity to the combination of caloric, and perhaps that the gasses themselves might be brought to a liquid or solid state by abstraction of heat. However as the least computation of the real zero places it at least five times the distance between freezing mercury and boiling water below any

observed cold, no material objection can arise to these computations from the probable effect of absolute cold on the hitherto uncongealable bodies.

The late Dr. Irvine, of Glasgow, was the first who instituted a theorem for the determination of the real zero, and this subject has been further examined by Crawford, Gadolin, and many other very accurate experimenters. Unfortunately there exist such material objections to the data which must be assumed as the bases of these calculations that a short notice in this place will suffice.

Dr. Irvine's most ingenious theory is founded on the comparison between the sensible heat given out when a substance passes from a state of greater to a less capacity for caloric, and the difference between the capacity in each state: thus it is ascertained that about 140° degrees of heat are given out when water is converted to ice (or, what amounts to the same, that ice at 32° , in thawing absorbs as much heat as would raise water at 32° to about 172°) and the capacity of ice is to that of water as 9 to 10. Water therefore contains as much *absolute* caloric as ice, and 140° degrees additional; and it is assumed that the absolute caloric of water compared to that of ice, is as their specific calorics, or as 10 to 9: and hence it follows that 140° is one-tenth of the absolute quantity contained in water, or that the entire quantity is 1400° . Or in other terms, the difference of the capacities before and after the change, is to the capacity after the change, as the sensible heat produced is to the whole number of degrees of heat which the body contained previous to the alteration in its form.

Another method given by Dr. Irvine of ascertaining the quantity of absolute heat is by the difference of temperature that generally results from the mixture of two bodies, compared with their respective capacities for heat. Sulphuric acid and water are very convenient examples, as the sensible heat evolved on mixture is very considerable. To render it a measure of the absolute heat, it should be produced merely from the capacity for heat of the mixture being less than the mean capacities of the two before mixture, relative to their respective weights. It unfortunately happens that experiments made with different mixtures by no means correspond or approach sufficiently to a correspondence to enable us to assume the necessary datum that the change of temperature only arises from a change in the capacity after mixture, and there-

* Crawford.

fore we shall merely refer the reader to Dr. Crawford's Treatise (p. 453 and seq.) for the calculations on this curious experiment.

It is also forcibly objected by Dr. Robison* that it is highly improbable that the proportion between the actual loss of caloric and the diminution of temperature (or the specific heat) remains the same towards the extremity of the scale of actual privation of heat as it does at the higher temperatures, the form still remaining unchanged. So that, though the calculations of specific heat may hold good experimentally in all practicable cases, it does not follow thence that the inference deduced from them can be extended to the extreme hypothetical distance which the determination of the actual zero would require. It is more analogous to other phenomena, as Dr. R. observes, to suppose that in the temperatures nearer to that of absolute privation, the quantities of heat necessary for producing equal elevation gradually diminish, as in most other progressions of natural operations. The hypothesis of Irvine and Crawford also supposes an equal uniformity in the comparative diminution of temperature in different bodies, to allow of the same point of absolute cold for all substances in nature. But it is equally improbable that this uniformity holds good for different substances at all temperatures, and hence we cannot with any certainty infer the absolute heats of different bodies from the estimation of the comparative specific heats that are within the limits of experiment.

The evolution of caloric by the mixture of different substances will be further noticed in the next section concerning

THE SOURCES OF CALORIC.

The two great sources of caloric that we are acquainted with, and whose mighty operations are constantly before our eyes, are the sun's rays and combustion. The great processes in nature and art that demand a supply of this principle receive it chiefly either from solar rays or culinary fire; but there are besides some other sources of caloric of considerable extent and importance, which cannot be arranged under either of the foregoing heads, and require a separate notice.

Of Chemical Mixture and Change in Capacity.

The evolution of sensible heat from any substance or substances when their specific caloric, or capacity for heat, is diminishing, has already been explained. Experiments on this head are the exact converse of the freezing processes by mixtures where the capacity is suddenly en-

creased; and it is so seldom that chemical action takes place between different substances, without a very sensible change in the capacity for caloric, that a rise or fall of the thermometer above or below the arithmetical mean may generally be expected on the mixture of bodies that have an affinity for each other, and is considered as a proof of intimate or chemical action. This source of caloric, though seldom acting with any great energy in natural processes, must in many instances be able, by its constant operation, to afford an adequate supply for very important changes. Dr. Crawford has with great ingenuity of research traced to this source no inconsiderable portion of the heat perpetually maintained in the living animal above the common temperature, having shewn that the arterial blood has a greater capacity for heat than the venous, and consequently that it must, on this account, give out sensible caloric in the natural progress of the circulation. Likewise all the processes, natural or artificial, in which gases are absorbed and condensed by liquids and solids, or liquids by solids, must be heat-evolving processes from the diminution of capacity attending these changes of state.

Some of the most powerful and familiar instances of the evolution of heat from mere mixture without a change of state, are, on adding water to alcohol, and to the nitric, and especially to the sulphuric acid. With the last, the heat produced on mixing nearly equal portions is much above that of boiling water.

In all these instances it has been attempted to be shewn by Drs. Irvine, Crawford, and others, that the evolution of caloric was very exactly proportioned to the change in the specific caloric, and indeed the calculations on the subject of absolute caloric require this proportion to hold uniformly. So that according to these philosophers, the caloric can hardly be said to be *chemically* united with the bodies that evolve it on mixture when the capacity is lessened, and the term *capacity* is somewhat better adapted to their conception of the mode of union.

But it has been shewn that a mere change of capacity will not account consistently for all the cases of evolution of heat on mixture, for there is an utter want of tolerable correspondence in all the calculations that have been made of the real zero derived from very different sources. The vast quantity of caloric given out in the slacking of well-burnt lime cannot be brought to tally with the proportional quantity that appears on mixing sulphuric acid and water (for

* Notes to Black's Lectures.

example) relatively with the mutual capacities; and hence we are compelled to incline to the hypothesis (in itself by no means strained or improbable) that caloric may truly and chemically combine with bodies and lose all its distinguishing characters, till it is expelled by stronger affinity, as any other body loses its specific characters by chemical union, and regains them as soon as that union is broken. Thus, in the above example of lime, it is certain that a part of the heat arises from the solidification of the water, or its change of state from a fluid to a solid; and another part perhaps arises from the capacity of slacked lime being less than the mean capacities of the lime and of water, but a third portion may be ascribed with high probability to the expulsion from the lime of a quantity of caloric, owing to the elective affinity of water being the strongest of the two. This caloric would readily be furnished by the fuel during the previous burning of the lime, and hence this earth in its *quick* or *caustic* state might perhaps be considered as a compound of lime and caloric, exclusive of that quantity of caloric which is inherent in all natural bodies, and which is alone considered in the estimation of *specific* caloric.

As an additional argument for this chemical combination of an excess of caloric in quicklime, it may be added that calcined Plaster of Paris will absorb and render solid to the full as much water as lime will, but with scarcely any change of temperature, and yet the substance whose change in capacity is the most reduced by the combination (that is, the water), is the same in both instances.

Many other examples of violent heat on mixture might be adduced, which seem to demand the hypothesis of a chemical union of caloric in one or other of the substances: but some of them, such as the heat and inflammation produced by the nitric and oxymuriatic acids, belong to the subject of combustion.

Of Friction and Percussion.

The heat which is elicited by (apparently) simple mechanical means, by rubbing, hammering, and the like, cannot be satisfactorily referred to change of capacity, or to combustion, and so little is yet known on this head that we must be content with the mention of the facts. The heat from percussion is very well shewn by the method often used by blacksmiths, of hammering a piece of cold soft iron till it is quite hot enough to kindle a sulphur match. This is performed in a few minutes by vigorous ham-

mering. It is to be observed that iron thus treated becomes much harder and denser, and when cold cannot again be brought to the same heat by the same means, unless it is first *annealed*, that is, heated red hot in the fire, and allowed to cool spontaneously in the air, when it again returns to the state of soft iron. The rudeness of the experiment renders it impracticable to estimate the absolute quantity of caloric given out during the hammering, but as it is obviously connected with the alteration of the texture of the metal, some have supposed that the heat is forced or squeezed out by a simple mechanical action, somewhat in the way that water is squeezed out of a moist sponge; and hence that the annealing causes a quantity of heat to adhere to the metal by a very loose combination. In all the cases of the evolution of caloric by percussion, the substance decreases in capacity for caloric, in proportion as its density increases. Thus, metals become heated by lamination, and when denser, their specific caloric is less than before. No heat is produced in dense fluids by the mutual friction or percussion of their particles in any way, and fluids are nearly incompressible, so that their capacity for caloric cannot be altered by mechanical means. On the other hand the compression of gases produces very considerable heat, as in the air-gun experiments and others already related. These facts would indicate that the cause of the heat from percussion and mechanical compression was simply the change in the capacity for caloric; but though this is certainly true to a considerable extent, it does not appear that the evolution of caloric is uniformly proportional to the change in capacity, and the phenomena of friction point out a distinct and hitherto inexplicable source of caloric which may combine its action, in many cases of percussion, with the proper effects of change in specific caloric.

The examples of the production of heat by friction are innumerable. Wherever machinery requiring rapid motion is used, every one knows the heat which is produced, and when the machinery is combustible, the great precautions requisite to avoid its destruction by the heat which its motion excites. The use of lubrication is not more to lessen the mechanical obstacles to free motion, than to prevent the great accumulation of heat by friction. Ungreased carriage wheels taking fire, gunpowder or cotton mills destroyed by overheating the machinery, are familiar examples of this fact: and the method still employed by man in the

savage state to kindle fire, is well known to be the friction of two sticks or other combustible substance.

In exciting heat by friction it is obvious that the hardest bodies are those which, *ceteris paribus*, would produce the greatest mechanical impediment, and therefore ought to give out the most heat. Thus a hard twisted cord drawn violently through the hand will produce a more severe burn than the same loosely twisted. But the hardest bodies, such as metals and stones, are also the best conductors of heat, and hence it may often happen that a given intensity of heat will be sooner accumulated in a soft substance of difficult conducting power than in the hardest metal.

Mr. Picotet found in some experiments on friction¹ that much more heat was produced by the friction of wood on wood, than of brass on brass, and the most of all when a few filaments of cotton were interposed.

The most accurate, and from the large scale in which they were carried on, the most striking experiments on the heat arising from friction, are those which Count Rumford² made at the ordnance-foundery at Munich, with the machinery employed to bore cannon. The leading particulars are the following: a cylindrical piece of brass (being a waste portion of a six-pounder brass cannon) weighing about 113 lb. was fixed in the boring machine, and a blunt steel borer was introduced and forcibly pressed against the inside with a pressure equal to the weight of 1000 lb. The cylinder itself was then made to revolve on its axis, and thus to work against the bore (as in the usual method of hollowing cannon) by a two-horse power. The cylinder was wrapped up in flannel to retard the dispersion of heat. In 30 minutes (or after 960 revolutions) a thermometer laid in contact with the cylinder in a place hollowed out for its reception, rose from 60° to 130°, so that the temperature of at least 113 lb. of metal had been raised 70 degrees, and this quantity of heat would have been sufficient to boil 5 lb. of ice-cold water. To prevent all possibility of any portion of this heat having been furnished by the air, Count Rumford repeated the experiment with an ingenious contrivance for causing the borer to work in vacuo, and an equal effect was produced as in the former case. The third experiment was still more striking. The whole apparatus was inclosed in a water-tight box, and covered with about 2½ wine gallons of water at 60°, and the borer set in motion. The heat

thereby generated was communicated to the water, the temperature of which rose in one hour from 60° to 107°; in half an hour more to 142°; in another half-hour to 178°; and in twenty minutes more it actually boiled. Thus therefore 2½ gallons of water were heated 152 degrees by strong friction for two hours and twenty minutes, besides an equal rise in the temperature of the brass cylinder, weighing 113.33 lb.; of 36½ cubic inches of iron and steel in the borer and other apparatus, besides what was dispersed in the air and communicated to the box. By very fair estimation, the whole heat thus generated was more than equal to have raised to the boiling point 26.58 lbs. avoirdupois of water at 32°: or (by inference from some of Dr. Crawford's experiments) it would have required the united effect of more than nine wax candles three-quarters of an inch in diameter, and applied in the most advantageous manner, to have heated as much water to the same point.

In the above experiments the question arises whence this large accession of heat could have been derived? It is obviously generated by the friction, and apparently in a very uniform manner; but no other sensible effect is produced by the borer than that of turning out a large quantity of fragments of brass (somewhat resembling wood shavings in form) and possibly, by the great pressure, a slight condensation of the remaining hollow cylinder of metal. But the turnings of the brass come out quite bright and metallic, and have undergone no obvious chemical alteration whereby caloric could have been elicited, and therefore we must either account for the heat by the diminished capacity for caloric of the brass turnings, or acknowledge friction to be a source of heat entirely distinct from any we have hitherto examined. To ascertain the capacity of the brass turnings, Count Rumford added 1016.5 grains of them at 210°, to 4590 grains of water at 59.5°, and the common heat after mixture was 63°, whence by Crawford's rule the specific caloric of the brass turnings is .110. An equal quantity of thin slips of gun-metal cut out by a fine saw was examined under similar circumstances; and the common temperature and of course the specific heat were found *precisely the same*. Hence (even allowing a little higher specific caloric in *cast* brass over the turnings from the borer) the utmost effect of this could only account for a very minute portion of the actual heat produced by the friction, nor is it probable or even possible that

¹ Essai sur le Feu.

² Phil. Trans. 1798.

any simple condensation of the sides of the remaining hollow cylinder of brass would do more. Friction therefore is a totally distinct source of caloric, and apparently unlimited in its action; for as long as it is kept up, the evolution of heat continues uninterruptedly, nor has any approach been made to an exhaustion of the supply. In this respect it differs from percussion. It may be added that the most powerful arguments against the materiality of caloric are drawn from this source.

Of Solar Heat.

The direct passage of caloric from the sun, and Dr. Herschel's important discovery of caloric rays separate from those that occasion light and colour, have already been noticed under the head of *radiant caloric*. Some other of the chemical facts connected with the solar rays will be described under the article *LIGHT*.

The intensity of the heat produced by the direct rays of the sun, collected by a lens or reflected by a concave speculum, is equal, with powerful instruments, to any other method of raising heat; but of course it must be confined to a very small spot. Solar heat, when it can be procured steady and for a sufficient length of time is most admirably adapted for very delicate and complicated experiments, as no error can arise from the introduction of burning fuel: and with caution, the pencil of rays from a lens or mirror may be transmitted through a glass vessel to any object contained within it.

The heat of the direct rays of the sun (simply thrown on any object without being collected by any glass or mirror) is much greater than generally appears by the thermometer, much of it being dispersed by the air through which it is transmitted, especially when in brisk motion.

When the sun's rays are confined to any spot, as much as may be, by being surrounded with bad conductors and protected from wind, the accumulated heat easily rises to a much greater intensity than the highest temperature of a tropical sun. M. de Saussure made an experiment to this point.* He made an oblong box one foot long and nine inches in width and depth, of half-inch deal, and lined it on the inside with cork an inch thick, and charred on the surface. A cover was fitted on, made of three panes of glass close fitting and parallel to each other, with $1\frac{1}{2}$ inch of space between each. When this was set in a hot sun the heat had to penetrate the three glasses, and was constantly accumulating in the box to a given degree, being confined on the three sides by the burnt cork

and thick walls of the box, and on the fourth by the two strata of air at rest contained between the glasses; all bad conductors of heat. On the top of a high peak of the Alps (on which for a particular purpose the experiment was first made) the box was exposed to the sun's rays for a considerable time, and a thermometer, which in the free air (hung 4 feet above the ground, and in the full sun-shine) stood only at $45\frac{1}{2}^{\circ}$, rose gradually within the box to $190\frac{1}{2}^{\circ}$. The rise of the last 46 degrees was effected in an hour. The thermometer laid on a piece of charred cork in the open air rose to $79\frac{1}{4}^{\circ}$. At the bottom of the mountain, nearly 800 fathom lower, the respective temperatures under similar circumstances of exposure were, suspended in the free air $74\frac{3}{4}^{\circ}$, within the box $187\frac{1}{4}^{\circ}$, and laid on cork $92\frac{3}{4}^{\circ}$. Similar experiments by Professor Robison^b gave a much greater effect, the thermometer rising within the box to 230° and 237° .

Of Combustion.

The last source of caloric to be mentioned is that which appears, in union with light (together constituting *Fire*) in the process of combustion: and the heat employed for all culinary, domestic, and manufacturing purposes, is almost entirely derived from this source.

The necessity for a constant supply of air to maintain combustion in all common cases, first led chemists to the important analysis of atmospheric air, and the distinct properties of that constituent of air which alone is active in maintaining combustion and respiration, and to which the modern system of nomenclature has given the name of *OXYGEN*. Under this article, and that of *PHLOGISTON*, the different theories of combustion will be described, but it may be here added that the caloric contained in oxygen and given out during combustion is not solely that which is requisite to the gaseous state, but in all probability is an essential constituent of this substance.

When a solid substance is burnt in oxygen gas, and the result is a solid or liquid, it might indeed be supposed that the evolution of caloric was owing to the change from the gaseous state to one of much less capacity for heat; but in a variety of instances the caloric produced by combustion is by no means proportioned to the quantity of oxygen gas consumed, and what entirely overthrows this hypothesis is the intense heat given out by gunpowder and various other combustible mixtures with the nitric or oxy-muriatic salts, in which the oxygen is not in

* *Voyages dans les Alpes*, tom. 2. p. 365.

^b *Notes to Black's Lectures*, p. 547.

the state of gas, but on the contrary is solid and condensed, and therefore can contain no caloric but that which must be considered as one of its essential constituents.

For the connection of light with caloric, see the articles LIGHT, OXYGEN, and PHLOGISTON.

CAMELEON MINERAL.

The chemical compound known by this name is so called on account of the changes of colour which it exhibits. It is thus prepared. Take one part of common black oxyd of manganese finely levigated, mix it with five parts of purified nitre, and fuse the mass for about half an hour at a high heat in an earthen crucible. A dark green mass is thus produced, which deliquesces on exposure to the air, and must therefore be kept in a well stopped vial. This substance readily dissolves in hot water, making a dark green solution: after the solution has been kept for a few days in a close vessel, a yellow powder begins to precipitate, and the liquor becomes of a fine blue: this blue liquor being diluted with common water assumes a violet colour, which afterwards grows red, and finally loses its colour, a grey oxyd of manganese being thrown down; by the addition of a few drops of acid to the blue liquor the change to red is instantaneous, and the colour is a very beautiful tint between crimson and pink. The cause of these changes is probably the following.

Black Manganese consists of the mixed oxyds of Manganese and Iron, both of which are soluble by fusion in caustic alkali: the natural colour of alkali with manganese is blue, and that of iron with the same is yellow: by the union therefore of these colours a green is produced. When the solution has been kept a few days the oxyd of iron separates, and the green colour being deprived of its yellow part becomes blue. Oxyd of manganese in a very finely divided state is of an amethystine red colour, as soon therefore as the oxyd of manganese begins to quit the alkali, the blue liquor becomes mixed with red particles and therefore is at first violet; and, as the red particles increase, becomes pink; finally, when the manganese is entirely precipitated the liquor loses its colour, and the metallic oxyd by having its particles condensed, becomes of a blackish grey.

CAMPEACHY WOOD. See LOGWOOD.

CAMPBOR. *Kampher*, Germ. *Camphre*, Fr.

Camphor is a colourless transparent substance, of a granular or foliated fracture, and a considerable resinous lustre: it is somewhat unctu-

ous to the feel; it possesses a certain degree of toughness, yet may be crumbled between the fingers without difficulty. It has a penetrating fragrant and highly refreshing odour; to the taste it is bitter and penetrating, rather heating at first, and afterwards remarkably cooling. It is volatile in a moderately warm temperature, and may be melted by heat suddenly applied. It burns with a large white flame and dense smoke. Its specific gravity is ≈ 0.996 , so that it just floats on the surface of water, and very small pieces thus floating may be set fire to, and will continue burning till they are almost entirely consumed. Camphor is the produce of a large forest tree, the *Laurus Camphora*, which grows wild in Borneo, Sumatra, and probably in several other of the Indian islands. The leaves of this tree give out when bruised a very sensible odour of camphor. The camphor itself is found concreted in perpendicular veins near the centre of the largest and oldest trees, especially those which have not been pierced when young for the sake of the fragrant camphorated oil which they contain.* The tree being cut down and split, the camphor is picked out by means of knives, and the smaller pieces are separated from the wood by rasps. The camphor according to its purity is divided into three sorts, the two inferior of which are mixed with certain proportions of a coarse kind procured by distillation from the native oil of the tree. The preparation of each kind for sale is simply by washing in warm soap and water. In Japan also is found a species of *Laurus* which yields camphor, but not in such quantity as the *Laurus Camphora*. It does not appear to be contained in a concrete state in this tree: but the roots and smaller branches afford it by distillation. For this purpose the roots being reduced into thin chips, and mixed with the twigs, are put into a net and suspended within a kind of alembic, at the bottom of which is a little water: by the application of a boiling heat the steam penetrates the contents of the net, and carries the camphor along with it into the capital, where it is deposited like snow on the straw with which the capital is lined. The Sumatran camphor is much more esteemed in the East than the Japanese, on account of a certain adhesiveness which it possesses, and in consequence of which it is much less volatile than that which has been obtained by distillation. All the camphor which comes to Europe is the produce of Borneo or Sumatra; and it arrives in the form of irregular pieces of a yellowish grey colour which are

* Asiat. Researches, vol. iv. p. 19.

spongy and very light, and when broken show that they are composed of small crystalline grains. The rough camphor is mixed with a very minute quantity of earth, from which both its colour and a slight grittiness between the teeth are derived.

The purification of crude camphor is an art which is carefully kept a secret by those who are in possession of it. Formerly this process was carried on only at Venice, afterwards it was successfully practised in Holland, and at present large quantities are refined by some of the English druggists. If the crude camphor is contaminated merely by earthy particles, the purification may be effected by simple sublimation without any addition; but as in some cases at least, the Dutch are in the practice of mixing lime or chalk in small proportions, it is probable that this addition is found of use in keeping down the oil with which the crude camphor is sometimes mingled. Spirit of wine has been proposed and employed on a small scale for the purification of camphor, but this menstruum besides being somewhat expensive, is incapable of separating any resinous substance which the crude article may contain.

Simple sublimed camphor differs from the refined camphor of the shops in being of a somewhat spongy granular consistence, but it may be made to assume the close and foliated texture of the latter by fusion, which is understood to be the method practised in the refineries: this may be done either by increasing the heat suddenly when the sublimation is almost ended, without transferring the camphor to different vessels, or by melting the sublimed flowers in a vessel for that purpose.

Although the camphor of commerce is obtained only from the *Laurus Camphora*, and a kindred species in Japan, yet its existence has been proved in many other species of *Lauri*; thus the roots of the Cinnamon tree (*Laurus Cinnamomum*) of the Sassafras (*Laurus Sassafras*) of the Cassia (*Laurus Cassia*) may be made to yield real camphor by distillation, though not in sufficient quantities to counterbalance the expense. The distilled water from the flowers of the *Anemone pratensis* has been found to deposit crystals of camphor by long standing.^b It has also been discovered in the fresh roots of *Galangale* (*Maranta Galanga*) *Zedoary* (*Kempferia rotunda*) and ginger; and in the seeds of cardamom and long pepper. It is probably contained in all the essential oils, and has been actually procured from those of juniper, sage,

hyssop, thyme, pepper-mint, rosemary, and lavender. The deposition of crystalline grains similar to camphor was first observed by Slarius in some old oil of cinnamon. Kunkel and Lewis confirmed this fact, and supplied some others of the same nature; Geoffroy, Cartheuser and Gaubius extended their experiments to most of the essential oils; and finally, Proust has taken the subject in hand, and from accurate and large experiments has shown that camphor may be profitably prepared from the essential oils in the southern countries of Europe.

This eminent chemist having accidentally observed^c that the essential oil of lavender distilled in Murcia, deposited a large proportion of camphor, and that the other oils of this province were remarkably fragrant, selected the essential oils of rosemary, marjoram, sage, and lavender, as the subjects of the following experiments. Equal portions of the four oils were placed in shallow earthenware vessels, and exposed to spontaneous evaporation at a temperature not exceeding 57° of Fahren. and in proportion as the crystals of camphor were deposited they were taken out and drained, and kept in well stopped vials: by this simple process the oil

of rosemary yielded 6.25 per cent. of camphor	
— marjoram ——— 10.14 ——— of camphor	
— sage ——— 21.06 ———	
— lavender ——— 25. ———	

The oil of lavender appears to be fully saturated with camphor; for although when heated it will take up about $\frac{1}{16}$ of its weight more of this substance, yet by cooling it deposits even a larger quantity than it was made to dissolve. When exposed to spontaneous evaporation the first filaments of camphor begin to appear in about twelve hours, and continue to be deposited till almost the whole is evaporated. In the other oils the crystals were later in shooting according to their relative proportions of camphor; and when about four-fifths of the oil was evaporated the residue became thick, and ceased to yield any more crystals. The camphor produced by each of the four experiments being dried by slight pressure between filtering paper was in dry, almost pulverulent crystals, as brilliant, and almost as white as snow, and so little of the peculiar odour of the oil remained, that it was by no means easy to ascertain by the smell alone from what species of oil any particular parcel of crystals was obtained.

The proportion of camphor procurable from these oils depends in some degree on the rate at which the evaporation proceeds, the quantity

^b Crells Chemische Journ. vol. i. p. 102.

^c An. de Chim. iv. p. 179.

being in an inverse ratio to the temperature. If oil of lavender is distilled from a water bath in an alembic, at a temperature inferior to boiling water, till one-third is come over, the remaining two-thirds will deposit flakes of camphor while cooling, these being removed, and the distillation being repeated, a fresh deposition will take place in the residue, and a third distillation will yield all the remaining camphor except about $\frac{1}{2}$ per cent. This however being a much more rapid process than spontaneous evaporation, the total produce of camphor from the three distillations does not amount to more than 20 per cent. the rest being held in solution by the oil in the receiver. If the *balneum marie* is made to boil, the produce of camphor will be considerably diminished, and part will sublime into the capital of the alembic. The camphor from oil of lavender by either of these methods is not absolutely pure, for when sublimed *per se*, at a gentle temperature, it leaves behind a small portion of brownish resin still mixed with a little camphor. The most economical way of refining this camphor is to mix it with half its weight of chalk, or lime, or washed wood ashes, and sublime it, by which operation it loses $\frac{1}{4}$ of its weight. The produce of refined camphor therefore by spontaneous evaporation of oil of lavender amounts to about 24 per cent. and by distillation is equal to 19 per cent.: this latter method however is by far the most economical, notwithstanding the additional expence of fuel and apparatus, as it saves both time, and the oil, which would otherwise be entirely lost.

The production of camphor by the action of muriatic acid on oil of turpentine is a discovery of very late date, and though it still requires some further elucidations, the leading facts appear sufficiently confirmed to justify their insertion in this place.* M. Kind, while preparing the arthritic liquor of Pott by passing muriatic acid gas through oil of turpentine, observed the mixture to deposit by cooling, a large quantity of crystals possessed in almost every respect of the characters of camphor. The experiment was repeated by Trommsdorff with the same result; and the society of pharmacy at Paris being informed of these facts, nominated three of their members to repeat the investigation, and make a report on the subject. From these sources the following information is derived.

A small quantity of camphor may be obtained from oil of turpentine simply by distillation, provided this process is carried on sufficiently slowly. Eight ounces of this fluid were distilled

in a glass alembic at about the temperature of 124° Fah.; four ounces of very highly rectified essential oil passed into the recipient, and the capital was found lined with small crystals of real camphor.

This substance is however procured in much larger proportions by the assistance of muriatic acid. Four pounds of oil of turpentine were put into a Woulfe's apparatus, and the retort being charged with the same weight of decrepitated muriat of soda, and half as much sulphuric acid, the whole of the muriatic acid gas that could be obtained by a moderate heat from these materials was transmitted into the oil of turpentine, and wholly absorbed by it. In consequence of this the oil became exceedingly hot, and acquired first a light lemon colour, and towards the end of the process a clear transparent brown, a small quantity of a thick oily fluid being gradually disengaged and sinking to the bottom. The liquor being allowed to cool for twenty-four hours was found concreted into a soft crystalline mass, from which, when laid on a sloping surface the brown liquor drained away. Being then wrapped in filtering paper and subjected to moderate pressure, twenty-four ounces of a perfectly white crystalline matter were left behind of a peculiar odour, in some degree participating both of oil of turpentine and muriatic acid. The liquor which had drained from the crystals was placed in a cool cellar, and in the space of a few days was found to have deposited four ounces more of crystals, and two ounces additional were obtained by exposing it to a powerful freezing mixture. Thus four pounds of oil of turpentine yielded thirty ounces of crystals; or not far short of half its weight.

The crystals of rough camphor thus obtained acquired a dazzling white colour by simply washing with water, but still retained a terebinthinate odour; the washings were acidulous to the taste, having taken up a little muriatic acid, and were highly aromatic. Another portion of crystals being washed with a weak solution of pearl ash was found to resemble common camphor in its odour, that of turpentine having nearly disappeared. It was thought that sublimation would be still more effectual than washing in purifying this camphor, accordingly two portions of it were mixed, the one with an equal weight of charcoal, the other with quicklime, and were heated in glass alembics: the capitals soon became covered with radiating needle-shaped crystals of a brilliant white colour, entirely free from the terebinthinate odour, and

resembling that of camphor, only not quite so powerful. In this state it floats on the surface of water, and communicates to it a camphoric flavour; is very inflammable, soluble in alcohol, and precipitable from it by the addition of water. Nitric acid acts upon it in the same manner but more slowly than upon East Indian camphor; but it appears to be wholly insoluble in acetic acid.

The presence of camphor has been shown in such a variety of substances, in all of which when brought to the highest degree of purification it appears to be absolutely the same, that it may be considered as one of the secondary vegetable principles; and an accurate investigation of its properties and composition becomes an enquiry of considerable interest.

Camphor on account of its volatility requires to be kept in well closed vessels, it is not however by any means so easily evaporable as is generally supposed. According to Kunssemüller,^d pulverized camphor spread thin, and exposed to the air at a temperature not exceeding 52° Fah. does not lose more than half its weight in 16 weeks; the ratio of volatilization however rapidly increases with an increase of temperature. The moisture of the air also has a considerable effect, the loss of camphor being much greater in a humid atmosphere than in a dry one. The degree at which camphor melts is fixed by Venturi at 302° Fah. and, by dividing a mass that has been cooled slowly in the direction of its laminae, it appears to crystallize in octahedrons.

Water has little or no action on camphor; at a boiling heat however it takes up enough to acquire both the odour and flavour of this substance. By the assistance of gum-mucilage or sugar, it forms with water a whitish emulsion.

Alcohol at the usual temperature, will take up between a seventh and an eighth of its weight of camphor, and when boiling it will dissolve half its weight, the greater part of which is again deposited by cooling. If equal parts of camphorized alcohol and sulphuric acid are distilled together, the produce is camphorized ether, and a tenacious black resinous mass remains in the retort.^e Camphor is also copiously soluble in sulphuric, and probably in all the other ethers. When camphorized alcohol or ether is mixed with water, nearly the whole of the camphor separates in the form of curdy flakes, which being dried gradually, exhibit the camphor unaltered in any of its properties. Oils, both the

expressed, the essential and the empyreumatic combine with camphor, as also do the resins and balsams. The hardest and dryest resins are converted by it into a soft tenacious mass remarkably soluble in alcohol; it will even render copal considerably soluble in this fluid. The alkalies whether in their caustic or carbonated state have no action whatever on camphor: nor will they unite even when digested with oil or soap.^f

Sulphur and camphor will combine together by means of a very gentle fusion: the resulting mass is brittle when cold, but soft and tenacious when warm. The alkaline sulphurets will also unite by fusion with camphor, and retain it when dissolved in water: the addition of an acid throws down the sulphur and camphor in intimate combination with each other.^g

When set fire to in atmospheric air, and still more in oxygen gas, camphor burns with a copious white flame and black smoke, and is entirely consumed. A large quantity of carbonic acid is produced together with carburetted hydrogen. The ultimate constituent parts of camphor appear to be carbon, hydrogen, and oxygen, but in what proportions is not yet ascertained.

Camphor when distilled *per se* rises unaltered, but if mixed with bole in the proportion of four parts of the latter to one of the former, and subjected to dry distillation, it is converted to a butyraceous consistence; and by a second distillation with fresh bole is entirely resolved into a fluid colourless oil, and a small quantity of a watery acidulous liquor, smelling strongly of camphor: the bole is at the same time reduced to a black sparkling powder, being almost entirely deoxygenated. Clay, according to La Grange, produces the same effect. This oil of camphor, according to Kosegarten,ⁱ is nearly colourless, has a peculiar odour like that of thyme or rosemary, and bears a close analogy to the essential oils. It is soluble in alcohol and separable, unaltered, from its solution by agitation with water. It forms favonules with the alkalies. It is easily volatilizable by heat, but deposits on the edges of the vessel a white unflammable crust which is soluble in water. Nitric acid produces no other effect on it than tinging it of a reddish colour; and even a mixture of concentrated sulphuric acid and fuming nitric acid, only deepens its colour still more, and brings it to a somewhat thicker consistence.

Carbonic acid promotes in a remarkable degree the solubility of camphor in water.^k For this purpose let finely pulverized or precipitated

^d Journ de Phys. xxxv. p. 291.

^e Monnet in Journ. de Phys. v. p. 456.

^f Bindheim in Crell's neue. Entd. xi. p. 113.

^g Dorfurt, abhandlungen uber den Camphor.

^h De Camphora.

ⁱ Own Experiment.

camphor be mixed with water and put into the decanter-part of the apparatus, plate iii. fig. 47. then let carbonic acid be thrown in from the retort, and combined with the water by agitation, as long as any continues to be taken up; a highly carbonated water will thus be produced, in which a sufficient quantity of camphor is dissolved to make it both taste and smell very powerfully of this substance.

Vinegar and muriatic acid will each of them by digestion take up a small portion of camphor. The muriatic and fluoric acids, when in the state of gas, dissolve a considerable proportion of camphor, but deposit nearly the whole by the contact of water. Concentrated sulphuric acid dissolves camphor largely even in the cold, but by the assistance of a moderate heat it takes up so much as to form a thick homogeneous mass of a brown or black colour and a sulphureous odour, which when warm is fluid, but coagulates by a moderate heat, and by evaporation is brought to a resinous consistence. This compound is soluble in alcohol, but is decomposed by water: the camphor being disengaged with little or no alteration, and the mixture now no longer exhaling a sulphureous but a camphoric odour. The action of oxygen on camphorized sulphuric acid is remarkable. If one part of camphor is dissolved in eight parts of sulphuric acid, and this liquor is poured in a retort upon four parts of black oxyd of manganese and as much water, the result of a slow distillation of these materials will be acetous acid mixed with a very small portion of undecomposed camphor.

Nitric acid when somewhat concentrated dissolves camphor in considerable quantity at the usual temperature. The solution is of a very dilute yellow colour, and separates by standing into two distinct liquids: the lower consists of a mixture of nitric and camphoric acids; the upper fluid is of the consistence of oil, and is called *acid oil of camphor*; it is a combination of camphor and nitric acid. This oil is soluble in alcohol, but is decomposable with precipitation of the camphor by water or alkalies: the addition of oxymuriatic acid gas converts it at first to a rose colour, and afterwards to a full yellow, and in all probability acidifies the camphor.

The conversion of camphor into a peculiar acid by repeated distillation with nitric acid was first observed by Kosegarten, and was afterwards more fully elucidated by La Grange.

The process of Kosegarten is the following.*

Put one part of camphor into a retort with 12

parts of strong nitric acid, and distil it slowly to dryness; a large quantity of carbonic acid and nitrous gas is disengaged, and the acid in the receiver is covered with a thin stratum of acid oil of camphor: a small portion of the camphor sublimes into the upper part of the retort, and the mass at the bottom of the vessel is camphor approaching to the state of a vegetable oxyd. It has no longer the peculiar odour of the original substance, and when laid on a hot coal it evaporates with a somewhat resinous odour, but without undergoing combustion: it is soluble in alcohol but not in water. This oxygenated camphor by being distilled twice to dryness with ten parts of nitric acid at each process, is converted to a white pulverulent salt, soluble in hot water, and which has obtained the name of **CAMPHORIC ACID**.

The method of La Grange differs chiefly in requiring a smaller quantity of nitric acid.¹ He takes one part of camphor and four of nitric acid, and distils the mixture by a very gentle heat: the acid that passes over into the receiver, being mixed with four parts more of fresh acid, is returned upon the matter in the retort and again distilled. This is repeated five several times with 20 parts of nitric acid in the whole, and the operation is known to be finished when the liquor in the retort crystallizes on cooling. The produce of camphoric acid by either of the methods does not much exceed one half of the camphor made use of.

Camphoric acid when crystallized hastily appears as a mass of white silvery filaments, but by slow cooling assumes the form of parallelepipedal or rhomboidal plates, which effloresce on exposure to the air. To the taste it is slightly sour and bitterish: it reddens syrup of violets and tincture of litmus. It dissolves easily in alcohol and in hot water, but requires 200 parts of this fluid at the usual temperature for its solution. When heated it gives out a thick aromatic smoke, and is entirely dissipated: in close vessels it sublimes unaltered if the heat is not too great. The alcoholic solution of this acid is not decomposed by water, a circumstance that distinguishes it from benzoic acid, to which it bears a considerable resemblance. It is soluble in the expressed and essential oils and the mineral acids, and forms a precipitate with the muriat and sulphat of iron.

Camphoric acid unites with the salifiable bases forming a genus of salts, the **CAMPHORATS**. Of these very little is known. The neutral and earthy camphorats, which are the only ones

* Gren. Handbuch. ii. p. 227.

¹ Manuel, ii. p. 357.

that have as yet been the subject of any experiments, are all decomposable by heat, except the camphorat of ammonia, which sublimes unaltered. When exposed to the flame of a blow-pipe the acid burns off with a blue flame. The camphorats are decomposable with abstraction of the base by the mineral acids, and with abstraction of the acid by most of the metallic, barytic, and calcareous salts. The camphorats of lime, barytes, and magnesia yield their acid to alcohol.

The use of camphor in the arts is to assist the solution of resins in various menstrua. It is employed with success in cabinets of natural history to prevent the approach of insects, which appear to be stupefied and killed by the pungency of its odour. But its principal use is as a medicine both externally and internally.

CAOUTCHOUC. *Elastic Gum.*

This singular vegetable substance was first brought to Europe from South America about the beginning of the last century. But nothing was known concerning its Natural history till in 1736 a memoir was presented to the French Academy by Condamine, in which it is stated that there grows in the province of Esmeraldas, in Brasil, a tree called by the natives Hhevê, from the bark of which there flows, on its being wounded, a milky juice, which by exposure to the air is converted into caoutchouc. M. Freneau discovered the same tree in Cayenne, and transmitted an account of it to the Academy fifteen years after the first notice of it by Condamine. Later researches have proved that there are at least two trees natives of South America from which caoutchouc is obtained, namely, the *Hævea caoutchouc* and *Fatropia elastica*, and it is not improbable that it is yielded by other species of these genera. The American caoutchouc is generally brought to Europe in the form of globular narrow necked bottles like receivers, about an eighth of an inch thick, and capable of holding from half a pint to a quart or more. In its native country it is fabricated by the inhabitants into vessels for containing water and other liquids; and on account of its ready inflammability is used in Cayenne as the chief material for torches.

A substance possessing all the properties of the American caoutchouc has also lately been procured by Mr. Howison, a surgeon in Prince of Wales's Island, in the East Indies, from the juice of a climbing plant, the *Urceola elastica*, a native of that small island, and of the coast of Sumatra. The thickest and oldest

stems of the urceola yield by far the largest proportion of caoutchouc. If one of these is cut into, a white juice ouzes out, of the consistence of cream and slightly pungent to the taste. When exposed for a time to the action of the air, or more expeditiously by the addition of a few drops of any acid, a decomposition takes place; the uniform thick cream-like juice separates into a thin whitish liquor resembling whey, and the caoutchouc concretes into a clot or curd covered superficially with a thin coating of a butyraceous matter. If the juice as soon as collected is carefully excluded from the air, it may be preserved for some weeks without any material change, but at length the caoutchouc separates from the watery part in the same manner, though not so perfectly as it does by free exposure to the air. The proportion of caoutchouc contained in the juice of the oldest stems is nearly equal to two-thirds of its weight; the juice from the younger trees is more fluid, and contains a considerably smaller proportion of this substance.

According to the experiments of Mr. Howison, cloth of all kinds may be made impenetrable to water by impregnating it with the fresh juice of the Urceola, and the pieces thus prepared are expeditiously and most effectually joined together by moistening the edges with either the entire juice or even the more watery part, and then bringing them in contact with each other. Boots, gloves, &c. made of this impervious cloth are preferable even to those formed of pure caoutchouc, as they are more durable and retain their shape better. If a sufficient quantity of this juice could be obtained, the important purposes to which it might be applied are almost innumerable.

The colour of fresh caoutchouc is yellowish white, but by exposure to the air it becomes of a smoky-grey: American caoutchouc in the state in which it is brought to Europe, being formed of a multitude of extremely thin layers, each of which is exposed to the air for some time, in order to dry before the next is laid on, is of a yellowish smoky-grey colour throughout; but masses of East Indian caoutchouc being formed more expeditiously, are dark-coloured only on the outside: when cut into they are of a very light brown, which however soon deepens by the action of the air. Caoutchouc is perfectly tasteless, and has little or no smell, except when it is warmed, it then gives out a faint peculiar odour. The elasticity of this substance is very remarkable, and indeed is one of its most

* Asiatic Researches, v. p. 157.

characteristic properties. Slips of caoutchouc when softened by immersion for a few minutes in boiling water may be drawn out to seven or eight times their original length, and will afterwards resume very nearly their original dimensions. During its extension a considerable quantity of caloric is given out,^b which is very perceivable when the piece is held between the lips; and when it is allowed to contract a decrease of temperature will immediately take place. By successive extensions and contractions in the open air, and especially in cold water, its elasticity is much impaired and it refuses to return to its former dimensions; but when in this state it is put into hot water it imbibes again the heat which it had lost, and by degrees resumes its original size. At the temperature of about 40°, caoutchouc begins to grow rigid, its colour becomes much lighter, and it is nearly opaque; as the cold increases it becomes more stiff and harder, and in all probability by a pretty powerful freezing mixture would be made brittle. These changes however depend merely on temperature, for a piece of hard frozen caoutchouc perfectly recovers its elasticity by being warmed. The fresh cut surfaces of this substance will unite together by simple contact, and by a proper degree of pressure may be brought so completely in union as to be no more liable to separate in this part than in any other. Its specific gravity, according to Brisson, is 0.933. It undergoes no alteration by the action of the air at the common temperature. When boiled for a long time in water it communicates to this fluid a peculiar smell and flavour, and is so far softened by it that two pieces thus treated and afterwards strongly pressed together will form a permanent adhesion to each other.

When heated at a temperature nearly equal to that of melting lead, caoutchouc runs into a black viscid liquor of the consistence of tar, which does not concrete on cooling, neither does it dry by long exposure to the air. When held to a lighted candle it readily takes fire and burns with a copious white flame, and a large quantity of dark coloured smoke exhaling at the same time a peculiar but not unpleasant odour: from its smoke a considerable proportion of fine lamp-black may be collected. In dry distillation it gives out ammonia and carburetted hydrogen.

Concentrated sulphuric acid, especially when heated, acts with considerable energy on caoutchouc, reducing it to a black, friable, charcoal-like substance, at the same time the acid itself

is in part decomposed, sulphureous acid gas being extricated. When treated with nitric acid, azotic gas is disengaged, mixed with carbonic and prussic acids; oxalic acid is left in solution, and the residue is converted to a yellow brittle mass. By digestion in oxymuriatic acid the colour of caoutchouc is discharged; it becomes opaque, is indurated and somewhat wrinkled, resembling tanned leather; but appears to undergo no other change. Similar effects are produced, though more slowly by muriatic acid.

Ammoniacal gas, according to Dr. Thompson, is absorbed by caoutchouc, and forms a soft, glutinous and inelastic compound. The same able chemist also states that the fixed alkalies are capable of combining with and dissolving it: he has however omitted to mention the peculiar circumstances required for effecting this. If slips of caoutchouc are boiled for a long time in caustic potash, they appear to be slightly hardened, but undergo no other change; when the alkali is evaporated almost to dryness, and the caoutchouc begins to soften by the heat, a combination begins to take place between the two, and an extremely fetid smell like that of animal putrefaction manifests itself. By repeatedly washing the mass in hot water, its putrid smell is diminished, though by no means got rid of; it is soft, slightly clammy to the feel, and considerably elastic when extended, it resembles in its fibrous texture, its white colour and shining glossiness, the tendons of animals.^c

A somewhat similar effect is produced by liquid ammonia. Some pieces of caoutchouc being macerated in exceedingly caustic ammonia for more than a year, exhibited on examination the following properties. Their colour was changed to a perfectly opaque white, their bulk had not materially increased although a considerable quantity of liquid alkali might be squeezed out of them; their elasticity was somewhat diminished and they were slightly viscid externally. On exposure to a melting heat they crackled, shrivelled, and became contorted like pieces of animal fibre, and exhaled a faint odour, in which that of burning animal matter was evidently mixed with that which peculiarly belongs to caoutchouc. The inflammability was remarkably diminished: a piece held in the flame of a candle crackled exceedingly, and was evaporated without combustion, except a small portion that melted and blazed, and appeared to be the part which had escaped the action of the alkali.^d

^b Thompson's Chemistry, iv. p. 355.

^c Own Experiments.

^d Ditto.

Caoutchouc is soluble with ease at a boiling heat in the expressed vegetable oils, in wax, butter, and animal oil, forming viscid unelastic compounds.

Rectified oil of turpentine at the common temperature acts without difficulty on caoutchouc, first rendering it transparent and enlarging its bulk considerably, and in the course of two or three days effecting a compleat solution. The liquor is of the consistence of drying oil, and when spread thin upon wood it forms a varnish, which however is a long time in becoming dry. When mixed with wax and boiled linseed oil, it composes an elastic varnish, which is used in coating balloons.

The only menstrua for this substance from which it can be again separated unaltered are, ether, petroleum, and cajeput-oil.

The solubility of caoutchouc in ether was first discovered by Macquer, a circumstance which, from its frequent failure in the hands of other chemists, was very generally called in question till Cavallo cleared up the difficulty, by showing the necessity of employing *washed* ether for this purpose. If fresh made sulphuric ether is shaken in a vial with an equal quantity of pure water, the small portion of acid which it generally contains is dissolved out by the water, and the ether combines with about a tenth of its weight of this latter fluid. The washed ether is readily separated from the residual water by decantation on account of its superior lightness, and is now capable of effecting a compleat and speedy solution of caoutchouc. The solution is of a light brown colour, and when saturated is considerably viscid. A drop of it let fall into a cup of water immediately extends itself over the whole surface, and the ether being partly absorbed by the water and partly evaporated, the water is found covered with an extremely thin film of caoutchouc, possessing its elasticity and all its other characteristic properties. A similar effect takes place when cloth of any kind is soaked in the solution, or any hard surface is smeared over with it; on exposure to the air the ether is rapidly evaporated, and the caoutchouc which it was combined with is left behind. The affinity of this solution for caoutchouc is very great: if the edges of two pieces of caoutchouc are dipped in it and immediately brought in close contact with each other, as soon as the ether is evaporated they will be found to be perfectly united.

There are two circumstances which must always prevent the extensive use of the etheric

solution of caoutchouc, admirably qualified as it is in other respects for many useful purposes; these are, first, its expensiveness, and secondly, the extraordinary rapidity with which the ether evaporates, thus rendering it impossible to lay an even coating of this varnish on any surface, and clogging up the brushes by which it is applied. In order to form tubes or catheters of this substance, the best method is to cut a bottle of caoutchouc into a long single slip, and soak it for half an hour or an hour in ether: by this means it will become soft and tenacious, and if wound dexterously in a spiral form on a mould, bringing the edges in contact with each other at every turn, and giving the whole a moderate and equal pressure by binding it with a tape wound in the same direction as the caoutchouc, a very effectual union will be produced. After a day or two let the tape be taken off, and the cylinder of caoutchouc may be rendered still more perfect by pouring a little of the etheric solution into a glass tube closed at one end, the diameter of which is a little larger than that of the cylinder of caoutchouc; which being introduced into the tube will force the solution to the top of the vessel. Let the whole of the apparatus be then placed in boiling water, the ether will be evaporated, and a smooth and uniform coating of newly deposited caoutchouc will remain upon the cylinder.

Petroleum when rectified by gentle distillation affords a colourless liquid not to be distinguished from the purest naphtha; and this, according to Fabroni, has the property of dissolving one-seventieth of its weight of caoutchouc, and of depositing it again unaltered, by spontaneous evaporation. ^e It does not appear however that this menstruum has been much employed.

The solubility of caoutchouc in cajeput oil was first noticed by Dr. Roxburgh. ^f This is an essential oil procured in India from the leaves of the *Melaleuca Leucadendron*, and promises to be the most useful menstruum of this substance that has hitherto been discovered. The solution is thick and very glutinous. When alcohol is added, this latter unites with the essential oil, "and leaves the caoutchouc floating on the liquor in a soft semifluid state, which on being washed with the same liquor and exposed to the air, became as firm as before it was dissolved, and retained its elastic powers perfectly, while in the intermediate state between semifluid and firm, it could be drawn out into long transparent threads, resembling in the polish of their surface the fibres of the tendons."

^e Ann. de Chim. xii. p. 156.

^f Asiat. Researches, v. p. 167.

"of animals; when they broke the elasticity
 "was so great that each end instantaneously
 "returned to its respective mass. Through all
 "these stages the least pressure with the finger
 "and thumb united different portions as perfectly
 "as if they had never been separated,
 "and without any clamminess or sticking to the
 "fingers."

Alcohol has no action whatever on caoutchouc.

Although caoutchouc is procured in quantity only from the vegetable juices mentioned in the former part of this article, yet it appears to be contained in several other plants. It is contained in the milky juices of the Indian fig (*Ficus Indica*), and of the bread-fruit tree (*Artocarpus incisa*); the berries of the miseltoe, and probably all the vegetable barks that yield bird-lime, abound with it. The caoutchouc however obtained from these sources differs from that which we have been describing in retaining a greater or less degree of viscosity, and perhaps in other respects, for no accurate comparative experiments have yet been made to decide this point. An investigation into the properties and composition of the birdlime from miseltoe and holly-bark would in all probability lead to very interesting results.

The uses to which caoutchouc has hitherto been applied are the following. It is employed very extensively for rubbing out black-lead pencil marks from paper, hence its usual name of India rubber: it is of value to the chemist as a material for flexible tubes to gazometers and other apparatus: the surgeon is indebted to it for flexible catheters and syringes; and finally it enters as an essential ingredient into the composition of the best varnish for balloons.

CAOUTCHOUC *Mineral*. See BITUMEN.

CAPITAL. An article of CHEMICAL APPARATUS. See Appendix.

CAPUT MORTUUM. *Tête morte*, Fr. *Todtenkopfe*, Germ.

This term is at present obsolete: it was used by the old chemists to express the residues of distillations after all the volatile parts had been driven off by the action of heat. These residues were at first thrown away as of no value. Glauber was the first who particularly employed himself in their examination, and was rewarded for his pains by the discovery of sulphat of soda (Glauber's salt) in the caput mortuum remaining after the distillation of muriatic acid from common salt and green vitriol; and of sulphat of potash (*Sal secretum Glauberi*) in the residue

after the distillation of nitric acid from nitre and green vitriol.

CARBON. *Carbone*, Fr. *Kohlenstoff*, Germ.

CHARCOAL. *Charbon*, Fr. *Kohle*, Germ.

Although carbon is an essential constituent part of almost all vegetable and animal substances, and is contained in vast abundance in the mineral kingdom, yet it is of very rare occurrence in a state of absolute purity. When uncombined with any other body it is crystallized, colourless, intensely hard, and under its commercial and mineralogical name Diamond, is ranked at the head of the gems, and in proportion to its bulk is the most costly of all substances. The detail of its natural history and external characters will be given under the term DIAMOND, the chemical facts that have been discovered concerning it being all that we have to do with at present.

The first suggestion of the inflammable nature of diamond is due to Newton. This philosopher having observed that inflammable bodies in proportion to their density possess a greater power of refracting the rays of light than other substances, was induced to rank the diamond among them on account of the eminent degree in which it possessed this property. This conjecture was verified in 1694 by the members of the Academy del Cimento at Florence, who consumed several diamonds by placing them in the focus of a lens. Soon after Francis the first, emperor of Germany, contributed some diamonds which were consumed by the heat of a furnace. Rouelle, Macquer, Cadet, and D'Arcet repeated the same experiments with considerable attention, and found that by exposure to heat and air, diamond was not only evaporated, but actually burnt with flame; but that even a very high temperature when the air was excluded, produced no alteration in this substance.

In 1772, an experiment was made by Lavoisier which may be considered as the first attempt to effect a chemical analysis of diamond. He burnt a small piece of this substance in a jar of atmospheric air by means of a powerful lens, and found that the original bulk of the air had been diminished, and a quantity of carbonic acid was produced, whence he concluded that there exists a considerable analogy between charcoal and diamond. In 1785 Morveau discovered that diamond when dropped into melted nitre burns like charcoal, and without leaving any residuum. This fact suggested to Mr. Tennant a method of analysing diamond which was effected in 1795 with complete success. The

apparatus made use of on this occasion was a tube of gold closed at one end, and terminating at the other in a curved glass tube, so as to answer the purpose of a retort. By way of previous trial some purified nitre was heated in the tube till it became alkaline, and being then dissolved out by water the solution was found to be absolutely free from carbonic acid, as it did not affect the transparency of lime-water. Having thus satisfied himself with regard to the perfection of his apparatus, Mr. T. filled the tube with a quarter of an ounce of nitre and two grains and a half of small diamonds: the gold tube was then heated to a full red, and kept at this temperature for an hour and a half. The gas disengaged during the process was ascertained by the test of lime-water to contain only an extremely minute portion of carbonic acid. The alkaline residue of the nitre was then dissolved out of the tube by water, and not the least trace was found of the diamonds. The solution being mixed with muriatic acid a copious precipitate fell down, which being carefully collected was placed in a small glass globe with a tube annexed: mercury was then poured in to fill it, and the apparatus was inverted in a basin of the same fluid. Some muriatic acid was then introduced by which the calcareous precipitate was dissolved, and the carbonic acid that it contained was at the same time disengaged and collected in the annexed tube. The bulk of carbonic acid was something more than 10.1 ounces of water, at 55° Fah. 29.8 Barom. A second experiment was made in a similar manner with one grain and a half of diamonds, and the carbonic acid obtained occupied the space of 6.18 ounces of water, according to which proportion the bulk of the carbonic acid from 2.5 grs. of diamond would have been = 10.3 ounces. The carbonic acid thus disengaged was again combined with lime, and by heating it in a close tube with phosphorus the carbonic acid was decomposed, and its carbonaceous base which at the commencement of the experiment was diamond, assumed now the black colour and other characters of charcoal. The identity of charcoal and diamond is still further confirmed by comparing the quantity of carbonic acid produced from the combustion of each. Lavoisier, from several experiments which have been acquiesced in by all chemists as sufficiently accurate, has shewn that 1 part of pure charcoal requires 2.5 parts of oxygen for its acidification; or that 100 parts of carbonic acid contain 28 charcoal and 72 oxygen. Now as-

suming the medium of Mr. Tennant's experiments as approaching very nearly to the truth, it follows that 2.5 grs. of diamond yield 10.2 ounce measures of carbonic acid at 55° temperature, and 29.8 barometrical pressure. But 1 ounce measure is = 1.89 cub. inch, and 1 cub. inch of carbonic acid weighs 0.467 grain: therefore 2.5 grs. diamond yield 9.03 grs. of carbonic acid; and the correspondence of this with the proportion of charcoal deduced from the experiments of Lavoisier is manifest from the following equation,

: 100 carb. acid : 28 char. :: 9.03 carb. acid : 2.521 diamond

Since the publication of Mr. Tennant's paper the subject has been resumed by Morveau at the Polytechnic school at Paris, with no small parade and pretensions to accuracy; and as he has drawn from his experiments and calculations not only very different results from Mr. Tennant, but has made them the basis of a new hypothesis, it is requisite to enter into their examination with some minuteness.

^bA globular receiver of glass was filled with 11470 cubic centimetres (450 cub. inch.) of oxygen gas, and a diamond of the weight of 200 milligrammes (3.08 grs.) was placed within it: by the action of a powerful lens the diamond was consumed and carbonic acid produced. A quantity of barytic water was then introduced, and a white precipitate of carbonated barytes was thrown down, weighing when dried at 212°. 192 centigrammes: now, as carbonated barytes according to Pelletier contains 22 per cent. of carbonic acid, these 192 centigrammes represent 42 centigrammes (6.48 grs.) carbonic acid. The gas remaining in the receiver amounted to 11242 centimetres, and still contained carbonic acid, for on mixture with ammonia it experienced a diminution of somewhat more than 4 per cent. which gives 448 centimetres (8.21 grs.) more of carbonic acid. Hence it appears, that although 28 parts of charcoal and 72 of oxygen compose 100 parts of carbonic acid, yet the same quantity of carbonic acid requires only 17.88 diamond and 82.12 oxygen. M. Morveau therefore infers that diamond is pure carbon, and charcoal an oxyd of carbon, being composed of 63.85 carbon and 36.15 oxygen: this conclusion he considers as strengthened by the experiments on plumbago by Scheele, who found that twice as much charcoal was requisite to alkalize a given quantity of nitre, as of plumbago, and that 80 centigrammes of the same when distilled with 20 parts of nitre yielded 357 cubic centimetres of carbonic acid.

The above are the principal facts and inferences contained in the memoir of M. Morveau, against which the following objections may be urged.

1. Allowing the author all his facts, there appears to be an essential error in his calculations. The carbonic acid as estimated by him from the carbonat of barytes produced is = 42 centigrammes, and the carbonic acid indicated in the residual gas by the test of ammonia, amounts to 448 centimetres more;

now 42 centigrammes = 6.48 grains
448 centimetres of carb. acid = 8.21

14.69 grains

troy, being the total amount of carbonic acid. The quantity of diamond employed was = 200 millegrammes (3.08 grs. troy); therefore : 14.69 grs. carb. a. : 3.08 grs. diamond :: 100 : 20.9. Hence the proportions of diamond and oxygen in carbonic acid, instead of being as M. Morveau states, 17.88 diamond and 82.12 oxygen, ought to be reckoned at 20.9 diamond and 79.1 oxygen. But there will be a still nearer approximation to the proportions laid down by Mr. Tennant, if instead of estimating the carbonic acid from the carbonat of barytes and the quantity contained in the residual gas, we take as the basis of our calculations the quantity of oxygen consumed. Now this, according to Morveau, amounted to 677 centimetres, or 26.6 cubic inches; the weight of which, estimating the specific gravity of oxygen at .0013562, is = 9.12 grs. troy, and this added to 3.08 grs. the weight of the diamond, reduces the quantity of carbonic acid to 12.2 grs. instead of 14.69 as deduced from the former method. Therefore 1 part diamond requires 2.96 oxygen to produce 3.96 carbonic acid: hence 100 parts carbonic acid are composed of

25 diamond

75 oxygen

100

which is not very different from Mr. Tennant's second experiment, in which 1.5 gr. diamond yielded 6.18 ounce measures of carbonic acid, whence the proportions would be

27.4 diamond

72.6 oxygen

100.0 carbonic acid.

2. M. Morveau appears to have proceeded on

erroneous grounds in his estimate of the carbonic acid contained in carbonat of barytes. M. Pelletier^c states the component parts of the native carbonat of barytes at

22 carbonic acid

62 barytes

16 water

100

without, however, particularizing the experiments from which he obtained this result. But Klaproth from a series of unexceptionable experiments^d has clearly shown, that the native carbonat of barytes contains no water, and consists of

22 carbonic acid

78 barytes

100

Now M. Morveau's carbonated barytes was *artificial*, and dried only at 212°, therefore it doubtless contained a considerable quantity of water; and 22 per cent. must be a greatly exaggerated statement of its carbonic acid.

3. The experiments of Scheele which are brought to countenance these results are by no means sufficiently accurate for the purpose: concerning the first, this able chemist simply states, that "five parts of nitre are sufficient to decompose one of charcoal; whereas ten parts of nitre are required to produce the same effect upon one part of plumbago."^e Now, when it is considered that in these experiments the nitre and charcoal or plumbago were levigated together, and then projected into a red hot crucible, it will be obvious that the difference observed between the plumbago and charcoal is in a great measure owing to the superior specific gravity of the former, by which it was prevented from being thrown out during the detonation. With regard to Scheele's second experiment, not to mention the imperfection of the apparatus, which consisted merely of a glass retort with a bladder fastened to it; and that neither the temperature nor barometrical pressure of the gas was noticed, nor the carbonic acid which remained in combination with the alkaline residuum of the nitre, — overlooking all these objections, and taking the proportions as stated by Morveau, they will be found if they prove any thing, to prove too much. 80 centigrammes of plumbago afforded, says M. Morveau, 357 cubic centimetres of carbonic acid; there-

^a Memoirs de Chimie, ii p. 456.

^d Analyt. Ess. i. p. 223.

^e Essays, p. 247.

fore (reducing the whole to English measure)

: 60.9 grs. carbon. acid : 12.3 grs. plumbago : : 100 : 20.1

so that a less proportion of plumbago is required for the formation of carbonic acid than even of diamond, and this without taking into account the 5 per cent. of iron contained in plumbago.

If these objections to the experiments of M. Morveau are well founded, we must return to the deductions of Mr. Tennant, and consider charcoal and diamond as very nearly the same substance chemically speaking, though differing so materially in many other respects; and as bearing to each other the same analogy as chalk to calcareous spar, alumine to sapphire, flint to rock-crystal.

Diamond when placed in the focus of a powerful lens in contact with oxygen gas presents the following phenomena. It first becomes of a clear red, and soon after is apparently enlarged in bulk by being surrounded by a faint white light, indicating it to be in a state of combustion: minute black spots, having a leaden metallic lustre occasionally form on its surface, especially when there is a slight remission of the heat; the diamond gradually diminishes, and at length is entirely consumed without leaving the smallest residue. It is somewhat remarkable, that although in a state of actual ignition and surrounded with oxygen gas, it nevertheless immediately ceases to burn as soon as the focus of the lens is withdrawn. The best observations on the combustion of this singular substance by the heat of a furnace, are to be found in a valuable paper by Sir George Mackenzie.^f A diamond being placed on a thin piece of baked clay, was introduced into a muffle previously heated red hot: it soon acquired the same redness as the muffle, and in a few seconds more became visible by a bright glow. Being then removed from the fire it was found to have acquired a slight milky appearance, and its lustre was impaired, but no black specks were perceived on its surface. A diamond and a piece of plumbago were introduced together into a muffle; the latter was observed to exhibit the same luminous appearance as the former, only it began at a lower temperature. The air being excluded for a few minutes by closing the mouth of the muffle, both the diamond and plumbago lost their brightness; but this soon returned on again allowing the air to circulate through the muffle, and was increased in both by blowing on them with a pair of bellows. The temperature required for the combustion of diamond

is lower than has been generally supposed; Sir G. Mackenzie found that at 13° Wedgewood, the diamond had acquired the dim milky appearance just mentioned, and that the highest heat necessary for its complete combustion did not exceed 15°.

In order still further to ascertain the identity of diamond and charcoal, it was ingeniously suggested by the French chemists to attempt to convert iron into steel by means of diamond instead of charcoal. This was successfully performed by Clouet,^g and afterwards repeated with some variations by Sir G. Mackenzie, in order to obviate certain objections that had been raised against the accuracy of the experiment.

The above are all the chemical facts hitherto known concerning diamond or carbon in its purest state: we shall now proceed to treat of charcoal.

CHARCOAL.

The great consumption of charcoal is as fuel, and the most usual material of which it is prepared is wood. The most esteemed kinds of wood for this purpose are oak, chestnut, elm, beech, and ash; the white woods and those which abound in resin being commonly rejected. Large timber, besides being too valuable to be thus employed, furnishes only a very inferior flaky kind of charcoal, the best being produced from coppice wood, the stems of which are from half an inch to two inches in diameter. Pieces three or four inches thick are not indeed rejected, but they require to be cloven in four previous to charring, which is some additional trouble, and the produce of charcoal is smaller in proportion than of the entire pieces. The wood when first cut down^a is formed into large faggots, which are dried in the open air for two or three months, and are then in a fit state to be made into charcoal. For this purpose it is sorted into brush wood, the smaller stems, and the larger ones, the two latter of which are cut into trunchcons from two to three feet in length. A square or circular space about fifteen feet in diameter is then marked out in a dry sheltered spot, and the turf is carefully removed from its surface, which is beaten till it becomes quite hard, dry, and solid: a thick stake somewhat higher than the intended pile is driven into the centre of the area, and a thin stratum of brush wood is strewed evenly over the whole space serving as a foundation for the rest. Above the brush-wood is laid a stratum of trunchcons, taking care to place the thickest near the centre, and the thinnest at the edges: over this

^f Nicholson's Journ. 4to. IV. p. 103.
VOL. I.

^g An. Chim. xxxi. p. 328.

^a Arts et Metiers art. Charbonnier.
2.G.

is spread a stratum of brush-wood, and so on alternately till the pile has acquired the height of about six feet, forming a truncated pyramid, or truncated cone. The top and sides are now covered to the thickness of two inches more or less with dry earth, or the dust remaining from a former burning; and over all is laid neatly a covering of fods so as to exclude the air, except from the lowest stratum of brush-wood, and here the fods are laid with as great intervals between them as can be allowed consistently with giving a firm support to the upper fods which rest upon them. The pile being thus arranged one of the workmen mounts to the top of it, and withdraws the stake that was driven into the centre of the area, filling up the space with dry chips, and laying a lighted stick on the top. The fire soon begins to spread downwards, and torrents of smoke pour forth from the interstices between the lower fods and from the chimney in the centre: after some time a light column of flame rises out of the chimney which is immediately stifled by the application of a piece of turf laid lightly on, so as almost but not entirely to close the vent. In an hour or two the fire will have made considerable progress, and occasional explosions will take place, from the copious disengagement and sudden combustion of carburetted hydrogen, on which occasions all the vigilance of the workmen is required. The approach of an explosion is indicated by a rumbling kind of noise within the pile which terminates in a loud burst as if the whole mass was torn in pieces; no material derangement however happens except that a small part of the covering is thrown out of its place, the extent of the damage being indicated by the flame and smoke that burst forth. These orifices as soon as they appear must be carefully closed by a few spadefuls of dry earth. In twelve or fourteen hours the explosions will have ceased, and the smoke will diminish; the workmen must now begin gradually to close up the interstices at the bottom of the pile, beginning on the windward side, and then for the next twenty hours no further attention will be required except to see that no accidents happen: the fire quietly spreads towards the circumference, which when it has reached the smok almost entirely ceases, and the whole mass appears glowing in every part. The wood is now thoroughly charred, and nothing more is necessary than to extinguish the fire: this is done by throwing on a quantity of dried earth sufficient to cover the whole to the depth of a few inches,

and taking care to stop up all cracks as soon as they appear. In the course of the fourth day from building the pile, the charcoal is generally fit to be removed, and this is ascertained by making an opening into the mass while yet warm, and if the fire is entirely extinguished it is immediately taken to pieces, but if on exposure to the air it begins to glow the opening is carefully covered, and the breaking up of the pile is deferred to the next day.

The above is the French method of preparing charcoal; but the mode followed in Scotland with the most success differs so considerably from that just described, as to require particular mention. The French charcoal is chiefly calculated for culinary uses, and is therefore made of considerably smaller wood than the Scottish, which is entirely employed in the iron works. ^bThe process begins by raising a plot of ground a little higher than the surrounding surface, and bringing it to a slightly convex form. In the centre of this area is placed a circle of sticks, the loose ends of which are directed inwards so as to cross each other a few inches below the top, and thus form a kind of cup of the shape of an inverted cone. Round this interior circle are ranged successive concentric circles, formed by truncheons from one to ten inches in diameter, care being taken that the truncheons in any one circle are of the same diameter, and that one built of the largest wood is always succeeded by another of the smallest wood, in order that there may be as few interstices as possible. The outermost circle is composed of brush-wood. When the pile measures from twenty to thirty feet in diameter it is sufficiently large. A coating is now laid on of turf, the grassy side next to the wood, and dry earth is heaped up around the bottom of the pile, and well rammed down in order to prevent the admission of air. The mass is lighted in the centre, by dropping into the cup formed by the interior circle some dry lighted chips, and in proportion as these are consumed other small pieces are put in during the first four or five days. When the upper part of the pile is sufficiently kindled, a row of holes, each about two inches in diameter is opened a few inches below. The hole at the top is then closed, and the fire now completely kindled slowly descends to the circle of air holes. As soon as it has reached this point, which is known by a remarkable diminution of the smok and vapour; a second row of holes is opened at the distance of six or eight inches below the first

^b Masfet in Phil. Mag. iii. p. 12.

which are closed up again. In this manner the fire is conducted to the bottom of the pile in the course of about a fortnight: at this period the pile is covered up as accurately as possible till the fire is completely extinguished. Those pieces that are found to be not sufficiently charred are called *brands*, and are employed as fuel for the next fire.

The charcoal produced from the truncheons is laid by itself, and sold under the name of charcoal; that from the brush-wood is disposed of at a lower rate, and is called in the London market *small coal*.

Although charcoal prepared by either of the above methods is fully adequate to all the purposes of fuel to which this substance is applied, yet in the manufacture of gunpowder, and for some other uses, it is of essential importance to procure a charcoal of greater purity than common. This was formerly done by selecting stems of willow, alder, and some other of the aquatic trees, and charring them in the usual manner, but with peculiar care. Of late, however, a very considerable improvement in the preparation of the finer charcoal has taken place by charring or distilling the wood in closed iron cylinders. For this purpose a large cylinder of cast iron fixed in masonry over a grate, and

furnished at one end with a door capable of being accurately closed, and terminating at the other in a curved pipe, is filled with the chips or saw-dust of any kind of wood; the door being then closed and a fire lighted in the grate, the empyreumatic acid, and all the other volatile parts of the wood are driven off by the heat, which is increased till the contents of the cylinder are red hot. The fire is then withdrawn, the cylinder is allowed to cool, and a black shining and remarkably pure charcoal, in greater quantity also in proportion to the wood employed than by the usual way, is procured, admirably fitted for the use of the gunpowder makers, and apparently possessed of the same qualities from whatever kind of wood it is made.

The proportion of charcoal yielded by particular woods is liable to be so materially affected by the age, and the dryness of the wood and the method in which it is charred, as renders it almost impossible to obtain any correct results in the great way. The following table from experiments in the small way by Mr. Musket,^c will however be found to be interesting, as all the woods before being charred, were thoroughly dried and prepared as nearly as possible in the same circumstances.

100 parts of lignum vitæ	- - -	afforded	26.8	of charcoal, of a greyish colour, resembling oak.
----- mahogany	- - -	-----	25.4	----- tinged with brown, spongy and firm.
----- laburnum	- - -	-----	24.5	----- velvet black, compact, very hard.
----- chestnut	- - -	-----	23.2	----- glossy black, compact, firm.
----- oak	- - -	-----	22.6	----- black, close, very firm.
----- American black beech	- - -	-----	21.4	----- fine black, compact, remarkably hard.
----- holly	- - -	-----	19.9	----- dull black, loose and bulky.
----- fycamore	- - -	-----	19.7	----- fine black, bulky, moderately firm.
----- walnut	- - -	-----	20.6	----- dull black, close, firm.
----- beech	- - -	-----	19.9	----- dull black, spongy, firm.
----- American maple	- - -	-----	19.9	----- ditto.
----- Norway pine	- - -	-----	19.2	----- shining black, bulky, very soft.
----- elm	- - -	-----	19.5	----- fine black, moderately firm.
----- fallow	- - -	-----	18.4	----- velvet black, bulky, loose and soft.
----- ash	- - -	-----	17.9	----- shining black, spongy, firm.
----- birch	- - -	-----	17.4	----- velvet-black, bulky, firm.
----- Scottish pine	- - -	-----	16.4	----- tinged with brown, bulky, moderately firm.

Charcoal of wood, whatever care is taken in the burning to drive off all the volatile products, can never be entirely pure, as it must retain all the earthy and metallic ingredients of the wood, the proportions of which vary from $\frac{1}{50}$ to $\frac{1}{10}$ of the charcoal; for the more delicate operations of chemistry therefore, that species of charcoal is made use of which is procured from the com-

bustion of oily or resinous substances, and is known in commerce by the general name of *Lamp-black*.

Lamp-black is prepared in large quantities by the turpentine manufacturers from the impure resin that remains after the distillation of oil of turpentine, and other refuse matters of the same kind. These are burnt in iron pots, or in a fur-

nace appropriated for the purpose, and the dense smoke arising from the combustion is introduced into chambers hung with sack, upon the surface of which the soot or lamp-black is deposited, and whence it is swept off from time to time and sold, without any further preparation. Common lamp-black is not indeed pure charcoal, being mingled with some empyreumatic acid and a portion of resin in a state of imperfect decomposition, but after it has been heated to redness in a close vessel, all these impurities are driven off, and there remains behind a charcoal in a state of almost perfect purity, as it burns away with hardly any perceptible residue.

Charcoal is an excellent conductor of electricity and Galvanism, but transmits caloric with very great difficulty: a very short piece may be held by one end while it is heated red at the other, without conveying any notable warmth to the hand.

The combined action of air and moisture at the usual temperature upon this substance can scarcely be perceived, hence the advantage of charring the surface of stakes and piles that are driven into moist ground, it being found by long experience that these are much more slowly rotted than the soundest timber deprived of this covering.

Charcoal is infusible by the greatest heat that can be applied. When exposed to a high temperature in dry and perfectly close vessels, it loses little or nothing of its weight, but shrinks in size and becomes proportionably harder, denser, more compact, and of a very deep velvet black colour. But although charcoal is thus unalterable by heat when the air is excluded, yet when made red hot and exposed to the air, it readily undergoes combustion, and by uniting with oxygen is converted into a heavy gaseous acid, formerly called *fixed air*, but in the reformed nomenclature known by the name of CARBONIC ACID.

Pure oxygen gas produces, as might be expected, a much more rapid effect on charcoal than atmospheric air does; a piece heated at one end to the lowest state of redness, and plunged in this gas, immediately burns with an intensely white glow, unaccompanied by flame, and is speedily changed into carbonic acid. Twenty-eight parts of charcoal and seventy-two of oxygen, according to the experiments of Lavoisier, form 100 of carbonic acid.

Water is very obstinately retained by charcoal, partly on account of its porous texture, and in part probably on account of a strong mu-

tual affinity, but no solution of one in the other takes place even at a boiling heat: when however charcoal is red hot, or nearly so, it decomposes any water with which it may happen to be in contact, and unites with both the elements of this substance, producing with the oxygenous base, according as this is added to saturation or not, carbonic acid and *gaseous oxyd of CARBON*; and with the hydrogenous base a heavy inflammable air, CARBURETTED HYDROGEN. Common charcoal always contains more or less of moisture, and it is to the decomposition of this and the formation of the above-mentioned gases, that the blue flame is to be attributed which makes its appearance when charcoal is calcined in a close crucible; the cessation of the flame being a proof that nearly all the moisture is expelled.

Various gases seem to be absorbed with singular facility by charcoal. This fact had been observed by Fontana, Priestley, Scheele, Morveau, and Morozzo, but it is to the Dutch chemists Rouppe and Van Noorden that we are indebted for a most interesting series of new and accurate experiments on this interesting subject. It is absolutely necessary that the charcoal made use of in these researches should be entirely free from air and water, and two methods have been adopted successfully to secure this point. The one is to heat a piece of charcoal till it is incandescent, and then to remove it from the fire as quickly as possible, and extinguish it in mercury previously dried, taking care to keep it in this situation for an hour or more, that it may be completely cooled. The gas to be operated upon is then to be introduced into a glass jar over mercury, and the charcoal being still covered by the mercury is brought beneath the mouth of the inverted jar, into which on being let go it immediately rises, and thus comes in contact with the gas. The second method differs from the first merely in the manner of extinguishing the charcoal, by inclosing it while hot in an air tight copper box. This latter mode was that chiefly employed by Messrs. Rouppe and Van Noorden.^d These philosophers found that one part of charcoal absorbed in four or five hours three times its bulk of atmospheric air; that oxygen gas was absorbed, at first rapidly and then more slowly, in the ratio of 2.8 times its bulk; azot was taken up only in the proportion of 1.6, and hydrogen of 1.8, but in both these cases the absorption was instantaneous. Of nitrous gas 8.5 parts were slowly, and of carbonic acid 14.3 parts were very rapidly absorbed.

^d An. de Chim. xxxii. p. 3.

*The gasses thus taken up underwent no change except of form; the residues were unaltered, and the pieces of charcoal gave out the whole of the respective gasses with which they had been saturated on exposure to the heat of boiling water. The absorptions were effected at a temperature between 48° and 64° Fahr. and from repeated experiments it appeared that in a greater degree of cold a larger proportion of the gasses would have been taken up. If charcoal saturated with hydrogen in the manner above mentioned is introduced into oxygen gas, or even atmospheric air, a considerable absorption of the oxygen takes place and combines with the hydrogen, forming water: at the same time a quantity of caloric is given out sufficient to raise the thermometer from 52° to 100° . The result is the same if the experiment is inverted, that is if charcoal charged with oxygen is introduced into hydrogen gas. Charcoal saturated with hydrogen is capable even of decomposing nitrous gas, absorbing the whole of its oxygen and leaving behind only azotic gas. Charcoal saturated with azot decomposes atmospheric air, absorbing the whole of its oxygen, but has no action on hydrogen.

Charcoal is capable of entering into permanent combination with several combustible bodies. Its union with hydrogen will be treated of under the article CARBURETTED HYDROGEN.

The discovery of carburetted sulphur is due to Clement and Deformes,^e and is thus prepared. Fill an earthen-ware tube with small pieces and powder of newly burnt charcoal, fix it in a slanting direction in a furnace, and lute to the lower end a glass tube dipping into some water contained in a receiver. Fasten a glass tube also to the upper extremity of the earthen pipe, and fill it with short cylindrical pieces of sulphur, and fit a cork to the open end of the glass tube with a movable wire passing through its centre, by which the pieces of sulphur may be pushed at pleasure towards the earthen pipe. The apparatus being completed, light the furnace and heat the pipe very gradually: the gas contained in the charcoal will soon be given out, and as soon as it ceases cause the sulphur by means of the wire to approach the heated part of the apparatus. Allow it to remain at such a distance that it may melt as slowly as possible and trickle down among the charcoal, for if suddenly heated it will become pasty and materially impede the success of the experiment. If these precautions are duly observed, a yellowish oily liquid will soon be observed in the terminating

glass tube, which will drop into the water of the receiver and collect at the bottom of the vessel, without at all uniting with the supernatant fluid. The carburet of sulphur thus obtained is a transparent liquid, colourless when pure, but generally of a yellowish green tinge, and of a disagreeable slightly pungent odour, differing entirely however from that of sulphuretted hydrogen. Very pure carburetted sulphur may also be procured by distilling together at a high heat the sulphurets of antimony or mercury with charcoal; but the same process was tried ineffectually with iron and copper pyrites. The specific gravity of carburetted sulphur, though liable to some variations, may be stated at 1.3. It evaporates in the air with nearly the same rapidity as ether, and like this fluid sinks the thermometer during the process in a most remarkable degree. If a bell glass full of water is inverted in a basin, and a little of this liquid is introduced, and the whole is then placed within the receiver of an air-pump, as soon as the atmospheric pressure is reduced to about 9 inches of mercury, the carburet of sulphur will begin to assume the gaseous state, will rise in large bubbles to the top of the bell glass, without mixing with the water, which it will expel, and will again be reduced instantaneously and totally to the liquid state upon restoring the atmospheric pressure. Upon the application of flame, carburetted sulphur takes fire and burns like other inflammable liquors, it gives out a sulphureous odour and deposits both sulphur and charcoal. When kept in a closed vessel along with atmospheric or azotic gasses, it is dissolved by them in small proportion, and renders them inflammable. It combines with nitrous gas, and the mixture burns with uncommon brilliancy, like zinc. It is taken up also by oxygen gas, and produces a detonating compound that explodes with prodigiously greater violence than the mixture of oxygen and hydrogen, so as to make it a highly dangerous experiment when performed even with comparatively small quantities. When in the state of vapour it combines slowly with the caustic fixed alkalies, forming deep amber-coloured solutions. It unites with phosphorus, without however modifying its inflammability: it takes up by digestion a little sulphur, but has no action on charcoal. By alcohol it is reduced to a soft pasty consistence. It dissolves in cold olive oil very easily, deposits a little charcoal, and then assumes a crystalline form: the same effect happens when ether is substituted for oil.

Carbon is said by Proust to be capable of uniting with phosphorus, but this from an experiment of Clement and Deformes^f appears to be a mistake.

Two of the metals are known to unite with charcoal: when in combination with IRON it forms *steel*, and with COPPER it forms a peculiar substance, first noticed by Dr. Priestley, and named by him *charcoal of copper*.

The action of the alkalies upon charcoal has not yet been examined into with any accuracy. Caustic potash when digested for some time upon charcoal becomes partly carbonated, but the carbonic acid thus produced is in all probability to be attributed to the decomposition of a portion of water.

The undecomposable acids appear to have no action on charcoal; but the decomposable ones are deprived by it of their oxygen either in whole or in part, and the charcoal is converted into carbonic acid. Thus sulphuric acid by being passed through red-hot charcoal furnishes sulphur, sulphureous acid and carbonic acid. Nitric acid yields nitrous gas and carbonic acid; phosphoric acid yields phosphorus and carbonic acid. If charcoal highly dried and finely pulverized is shaken into oxymuriatic acid gas, it becomes immediately red hot, and falls as a shower of fire to the bottom of the vessel.

No affinity has been indicated between charcoal and any of the earths.

Of the neutral and earthy salts those with decomposable acids are strikingly altered by the action of charcoal at a red heat; the others suffer no material change. It is worthy of notice, that the decomposition which the acids undergo in these circumstances is much more compleat, owing to their fixity, than when they are subjected alone to the action of charcoal. Thus the sulphats are changed not into sulphites but into sulphurets, and the nitrats give out not nitrous gas, but azot. It is remarkable however that phosphat of lime is undecomposable by charcoal. The metallic salts are all of them decomposed by charcoal at a greater or less degree of heat in consequence of the metallic base being deoxygenated, independently of the action of this substance on their acids. Some of the most easily decomposable salts, as muriat of gold and nitrat of silver, when perfectly saturated may be decomposed in the moist way at a boiling heat, or by help of the solar light at the usual temperature by means of charcoal, the metal being deposited on the surface of the

charcoal with all its characteristic brilliancy and colour.

The effects of charcoal in clarification are both curious and important. They were first noticed by M. Lowitz of Petersburg, and have been for the most part amply confirmed by succeeding observers. In order to be employed this way with the greatest success, it is essential that the charcoal should be finely pulverized and very dry. For this purpose let some well-burnt common charcoal be rubbed in a mortar (with a few drops of water to prevent the dust from flying about) and afterwards passed through a fine sieve: fill a crucible with this powder, and lute on a pierced cover. When the vessel begins to be red hot a light blue flame will issue from the hole in the cover: the heat is to be continued, gradually increasing it for a few minutes after the flame has ceased: being then withdrawn from the fire, and placed in a dry situation till it is sufficiently cool to be handled, it must be quickly opened, and its contents transferred without loss of time into a perfectly dry well stopped bottle, in which the charcoal may be kept for any length of time without injury. The properties of this powder are very striking. Being mixed with common vinegar, or any kind of wine, a thick froth rises to the surface, and the liquors after filtration are found to be quite clear and entirely colourless. The filthiest and most putrid ditch water is in like manner rendered perfectly limpid, inodorous, and insipid, and rancid oils are deprived of their smell and taste by repeated filtration through a stratum of this prepared charcoal. Hence also its peculiar efficacy as a dentrifice, its particles are sufficiently hard to remove the concretions from the teeth without injuring the enamel, while it neutralizes and entirely destroys the foetor with which the breath is not unfrequently tainted from a carious tooth.

The affinity of charcoal for oxygen is so considerable, that instances have been known of its undergoing spontaneous combustion by simple contact with the air. An occurrence of this kind took place at the powder-mills of Essonne in France.^g A large quantity of recently burnt charcoal had been ground in the usual manner, and was deposited in a large receptacle for future use; some days after, the door of the magazine being opened in order to remove a part of the charcoal, an extraordinary heat was perceived, and immediately a train of fire was observed spreading over the surface of the char-

^f An. de Chim. xlii. p. 149.

^g An. de Chim. xxxvi. p. 93.

coal, which was not extinguished without much difficulty.

The uses of charcoal are very extensive and important. Its greatest consumption is as an article of fuel both for domestic purposes and in the working of metals. It is of indispensable necessity in the laboratory both as a fuel and an ingredient in all kinds of reducing fluxes. It is an essential constituent part of gunpowder, and is the basis of almost all black paints and varnishes. It is employed by mathematical instrument-makers and others in polishing brass and copper, and is used in many cases with great advantage as a simple and efficacious clarifier and purifier.

CARBONIC ACID.

CARBONIC ACID GAS. *Fixed Air. Aerial Acid. Mephitic Air. Kohlenstaure, Ger. Acide Carbonique, Fr.*

Carbonic acid is known to us only in its gaseous state when uncombined, and it is then the *fixed air* of Cavendish and Priestley, the *aerial acid* of Bergman, the *mephitic air* of other chemists. It was the first gas in which acid properties were clearly discovered, and many of its properties as a gas were known long before its existence was suspected in many of the compounds of which it forms a part. It is known to be an acid by the united characters of reddening vegetable blues, neutralizing alkalies and alkaline earths, and being formed by the union of a combustible base with oxygen.

Its alkaline, earthy, and metallic compounds are called *carbonats*, and will be described under that head; the properties of carbonic acid gas, and carbonic acid united with water, belong to the present article.

The sources of this acid are immense, and widely diffused throughout the natural world. The chief are the following:

1. The atmosphere always contains a small portion, which seldom varies except in the immediate vicinity of places where respiration and combustion are going on in the large way, and is about one hundredth part. Hence it is that alkalies and lime lose their causticity in the open air, by extracting its small proportion of carbonic acid.

2. Many mineral waters rise from the earth more or less strongly impregnated with this acid, much of which flies off in the gaseous form as soon as exposed to the atmosphere. The brisk frothing waters of Seltzer are examples of this kind.

3. Every process in which coal, wood, or any other carbonaceous substance is consumed, is one

which generates this acid gas; and hence there is no vegetable matter on the face of the earth which does not give this acid largely when burnt.

4. The respiration of animals resembles combustion in this respect, and hence there is a quantity of carbonic acid gas unceasingly pouring into the atmosphere from the lungs of every living animal.

5. The vegetation of plants is, under some circumstances, a process in which carbonic acid is generated, but is subject to more variations from external causes than respiration.

6. The spontaneous decomposition of vegetable and animal matter also generates carbonic acid, more especially the curious process of vinous fermentation, from which many of the most important properties of this acid were first observed.

7. An immense store of this acid is contained in the natural carbonats, more especially all the varieties of lime-stone, chalk, and calcareous stones, many of which contain as much as 40 per cent. of their weight of this acid.

Other smaller sources exist which do not require enumeration.

Carbonic acid gas, or fixed air, when procured by modes to be presently mentioned, has the following properties. It is quite permanent at any temperature, nor can it, without combination, be exhibited by cold or pressure in any other than a gaseous form. It is absolutely fatal to animal life, any living creature immersed in it perishing in as short a time as it would by absolute suffocation or interruption of respiration. Thus, small animals, such as mice, dropped into a vessel of fixed air die almost immediately; dogs become convulsed and senseless in about a minute, but recover in the open air if taken out very speedily; men and large animals nearly the same, according to their powers of life; frogs and cold-blooded animals who have always in their lungs a supply of air for many minutes, live in it without much inconvenience till that internal supply is exhausted, after which they perish. Fixed air is incapable of maintaining combustion for a moment. If a lighted taper is let down into a jar full of this air, the taper is extinguished as soon it reaches the level of the gas, as completely as if dipped into water. Even a small admixture of this air with common air prevents combustion; for Mr. Cavendish found, that a candle dipped in a jar holding only one-ninth of fixed air went out immediately.*

Carbonic acid gas is the heaviest of all the

* Phil. Trans. for 1766.

known gasses except the sulphureous. Its weight compared to that of common air is very nearly as 3 to 2 in all circumstances, hence its specific gravity will be about .001806, and the weight of a cubic inch at 60° and 29.5 inches bar. will be about 0.456 grains. On account of its heaviness, when generated, it falls rapidly to the ground, and spreads laterally over the surface, though after a time it mixes uniformly with the atmosphere. This is well shewn at the Grotto del Cani, a cave in the vicinity of Vesuvius, through the floor of which a quantity of fixed air is constantly rising from some subterranean reservoir. A man standing upright in it feels no inconvenience from the noxious gas, as it only rises to about the height of his knee, but if a dog or other small animal enters, it is presently suffocated.

Carbonic acid gas is procured for experiment generally from limestone, chalk, marble, or any of the carbonats of lime, either by heat, or more commonly by any of the stronger acids. The diluted sulphuric or muriatic are the acids mostly employed. The latter is perhaps preferable, as the muriat of lime resulting from the mixture remains dissolved, whereas the sulphat of lime from its little solubility crystallizes in the mass, and somewhat impedes the process. With small pieces of marble, and moderately strong muriatic acid, a constant and pretty uniform stream of gas is given out till the acid is saturated, or the whole of the marble dissolved. Marble yields in this way from 40 to 45 per cent. of its weight of carbonic acid gas, so that 100 grains will yield between 90 and 100 cubic inches. The disengagement of carbonic acid from any of the carbonats, whether alkaline, earthy, or metallic, is accompanied by a frothing or effervescence, occasioned by the carbonic acid assuming the gaseous form, or becoming carbonic acid gas, when detached from its combination by the affinity of the stronger acid to the base of the carbonat.

Heat is another method of obtaining the carbonic acid from the earthy carbonats. Chalk or marble enclosed in an earthen retort, and strongly heated, readily gives out this gas: carbonat of magnesia with still greater ease. The gas thus procured when united with water produces a less pungent liquid than that prepared by acids, so that probably the latter carries off with it a small portion of the acid used, and therefore is not so pure.

All substances undergoing the vinous fermenta-

tation also give a copious supply of this gas, which from its weight long remains hovering over the surface of the fermenting mass. Therefore substances placed in the vats of a brew-house just over the fermenting liquor, are thereby kept immersed in an atmosphere of carbonic acid gas, which however is not quite pure, being mixed with a sensible quantity of alcohol. See FERMENTATION.

Carbonic acid gas is readily absorbed by water, and this combination is found in a very high degree in several of the most esteemed *Mineral Waters*. Carbonated water, when the proportion of carbonic acid is considerable, has a very agreeable, brisk, pungent taste and smell, bubbles and froths strongly when exposed to the air, particularly when gently heated; and it is in this combination that the acid properties of carbonic acid are the most sensible, but when nearly at the freezing point the peculiar taste is hardly perceptible, though cold water will absorb more of the gas than warm.^b This natural combination may be very well imitated by art, and since the first experiments of Bergman, Priestley, and Cavendish, many very ingenious contrivances have been invented to effect this combination in very large proportions; as the carbonated water in various modifications, has become a very fashionable and salutary article for diet and medicine.

The absorption of carbonic acid gas by water is shewn in the simplest manner by the following experiment: fill a phial quite full of cold water, invert it over a cupful of the same, and throw up a quantity of the gas from a bottle with a curved tube, in which marble dust and muriatic or sulphuric acid have been put. As the gas rises into the inverted bottle the water is proportionally displaced, and when about half full of gas, stop the phial strongly with the finger, and shake together violently the gas and the water. A strong absorption will immediately be felt by the external pressure on the finger, and the water will be found sensibly to taste of carbonic acid.

Agitation therefore is one method of assisting the absorption, and strong pressure is another equally powerful. These are combined in a high degree in the forcing-pump apparatus used for preparing artificial mineral waters in the large way. The temperature also of the water much affects its absorbing power; for Mr. Cavendish early in the enquiry found that cold water absorbs much more than warm.

^b Bergman.

Water at about 50° may by common means be made to take up nearly its own bulk of fixed air, but in the large way with a strong forcing pump three times as much may be thrown in. Water thus highly carbonated must be inclosed in strong bottles corked with particular precautions, and when the cork is drawn, the liquor froths and flies out like very brisk cyder.

Mr. W. Henry in his valuable experiments on the absorption of gasses by water,^c has shewn that the quantity of carbonic acid absorbed under equal circumstances of temperature, pressure, and agitation, is also much regulated by the actual quantity of gas used, and by its purity, or in other words its proportion to the residual atmospherical air contained in the vessels and in the water before the experiment, which no boiling nor exposure in an exhausted receiver can entirely separate. Thus, if 20 measures of nearly pure carbonic acid gas be agitated with 10 measures of water at 55° , full 10 measures of the gas (or equal in bulk to the water) are absorbed: but if the same quantity of water at 55° be agitated with a mixture of 20 measures of carbonic acid, and 10 of common air, only 6 measures will be taken up by the water. This is somewhat analagous to the observation of Dr. Brownrigg, that in carbonated water, however saturated, the gas will not escape when inclosed in an air-tight vessel, with an empty and collapsed bladder communicating with it, though when exposed to air the gas flies off readily. The diminution of absorption in increased temperatures, Mr. Henry estimates to be about $\frac{1}{14}$ of the whole, for every 10 degrees above 55° . With regard to the effect of pressure, Mr. H. deduces from experiments, the general law, that "under equal circumstances of temperature, water takes up" "in all cases the same volume of condensed gas, "as of gas under ordinary pressure." Therefore as the volume of all aeriform bodies is always inversely as the compressing force, the quantity of gas absorbed is directly as the pressure to which it is exposed; as, for example, if the common atmospherical pressure, or that of about 30 inches of mercury, will cause the absorption of carbonic acid equal in bulk to the water, a pressure of two atmospheres must cause a double quantity to be absorbed.

The specific gravity of carbonated water containing its own bulk of carbonic acid, is about 1.0015.^d It must be taken in a low temperature, otherwise the perpetual escape of the gas would defeat the accuracy of the experiment.

By freezing, the water parts with the whole of its carbonic acid, just before it solidifies.

Water readily parts with its carbonic acid by being heated, and in this way it is collected in the analysis of the carbonated mineral waters. To expel the whole it is requisite to boil the water for ten or fifteen minutes.

The single test of the acidity of carbonic acid by the change of vegetable colours, takes place with the infusion of litmus, when added to carbonated water. When the water contains as much as $\frac{1}{16}$ of its bulk of this acid gas, it changes the blue of litmus to a red.^e This is most conveniently shewn by diluting the litmus infusion till it is of a very faint blue, putting some of it into a glass tube, and adding about as much of the carbonated water. If this is compared with an equal quantity of litmus liquor mixed with as much plain water in a similar tube, the difference of colour will be very apparent. To shew that the redness is produced by the carbonic, and no other acid, let another portion be mixed with the carbonated water, previously boiled a few minutes to expel the acid gas, and no change of colour will now appear.

Lime-water is a much more delicate test of carbonic acid, either in its gaseous state or united with water, or even in combination with an alkali. In all these cases, whenever lime-water comes in contact with carbonic acid, the lime eagerly absorbs it, and becoming thereby insoluble in mere water, it falls down in the form of a fine white precipitate, rendering the water milky, as when chalk is diffused in water. A very small portion of carbonic acid will produce this effect, and hence it is that lime-water becomes cloudy and collects a white pellicle on the surface by mere exposure to air, the atmosphere containing on an average about one per cent. of carbonic acid. It is also very well shewn by blowing air from the mouth through any small pipe dipping in a glass of lime-water. The breath contains about 5 or 6 per cent. of carbonic acid, which presently renders the lime-water entirely turbid. When the acid is in solution the power of this test is equally great, discovering immediately, according to Bergman, about one cubic inch of the gas in 7000 grains of water, being $\frac{1}{14000}$ of the whole. It should be observed however in using this test, that an excess of carbonic acid redissolves the first precipitate of carbonate of lime, so that there should always be an excess of lime-water to engage all the carbonic acid it meets with. Thus if a very

^c Phil. Trans. for 1803.

^d Bergman.

^e Ibid.

strong carbonated water and lime-water be mixed together at intervals, the mixture will become turbid by the first portion of carbonated water, then by more of the same it will become quite transparent; then, a fresh portion of lime-water will again make it turbid; an excess of carbonated water will again redissolve the precipitate and make the liquor clear, and so on alternately.

Barytic-water and Strontian-water are equally good tests with lime-water, and the two solutions holding more of the respective earths, they are more active in their operation.

When carbonic acid gas is contained in any gaseous mixture, it is detected and readily absorbed by the above-mentioned tests, and the loss which the whole gas experiences on being shaken with the test, indicates the quantity of carbonic acid contained. A solution of caustic or semi-caustic fixed alkali is a still better substance to absorb the carbonic acid gas, as it may be made so strong that a very small quantity of alkali will take up a large portion of the gas, and the full effect is immediately produced. With the alkali there is no cloudiness or precipitate produced, so that the absorption is the only test of the presence of the acid gas.

It required the united efforts of many of the most eminent chemists to prove that the same substance which exists in a solid form in the hardest lime-stones, which gives the brisk taste and sparkling appearance to mineral waters, which is entangled in the froth of fermenting liquids, which is generated in the lungs of all living animals by respiration, and which performs a most important office in the functions of vegetable life, is the same that results from the combustion of charcoal and all carbonaceous matters, and therefore, according to the universally received theory of combustion, is composed of charcoal, the inflammable basis, united to a portion of oxygen sufficient to give it the properties of an acid. The full discovery and proof of this last fact is due to Lavoisier, and from this elementary experiment he was able to deduce the exact composition of carbonic acid and the proportion of its constituent parts.

For this purpose he introduced some well-burnt charcoal into a large bell-glass filled with oxygen gas, having previously kindled a minute piece of tinder with an atom of phosphorus adhering to it and in contact with the charcoal. As soon as the charcoal took fire, it began to burn in the gas with a very bright flame, throwing brilliant sparks in every direction. The combustion stopped long before the whole of the

oxygen was consumed, owing to the carbonic acid generated, and mixing with it; and hence too there was very little diminution of the entire quantity of gas, as takes place in the combustion of phosphorus, and many other bodies where the product is solid or liquid. When all was cold, the carbonic acid was subtracted from the residue by means of caustic alkali, the weight of which acid was very exactly equal to the united weights of the charcoal and the oxygen consumed, and by computing the proportions of the two, it was found that carbonic acid is composed of about 28 of charcoal and 72 of oxygen. Subsequent experiments by different chemists agree very nearly in the above proportions. Those of Clement and Deformes,^f made with picked charcoal heated strongly for an hour in a covered crucible, and therefore in the purest possible state, give 28.6 of charcoal to 71.4 of oxygen. No tinder nor phosphorus were used to kindle it, for when any portion of the charcoal is heated red-hot in the air, the instant the oxygen gas reaches it, the combustion becomes brilliant, sparkling, and rapid.

Carbonic acid is also produced by direct combination of carbon and oxygen when charcoal is distilled with the red oxyd of mercury;^g which metallic substance distilled without addition, is known to yield a very large quantity of oxygen gas.

Carbonic acid is at its highest state of oxygenation, and in any lower state it loses its acid properties. It is capable of decomposition either wholly or partially, furnishing many very curious experiments in each process.

Phosphorus is the only substance by which the carbonic acid has ever been completely decomposed by compound affinity, and its base left in the state of charcoal. This discovery is due to Mr. Tennant,^h and was followed by other valuable experiments by Dr. Pearson.

From the well known fact that the phosphoric acid cannot be decomposed by charcoal when united with lime (phosphat of lime not yielding phosphorus by distillation with charcoal) Mr. Tennant inferred that the united actions of phosphorus and lime would be sufficient to decompose the carbonic acid, and therefore that when carbonat of lime was heated with phosphorus, the latter would absorb oxygen from the carbonic acid, and be acidified at its expense. He accordingly put a little phosphorus into a glass tube, closed at one end and coated with sand and clay, and over the phosphorus some powdered marble. The other end of the tube was

^f An. Chem. tom. 39.

^g Priestley.

^h Phil. Trans. for 1791.

ⁱ Phil. Trans. for 1792.

then closed up, leaving only a very small opening for the heated air to escape. After heating the tube red hot for a few minutes it was removed from the fire, and when cold, was broken. It contained a black powder, consisting of charcoal mixed with a compound of phosphat of lime or lime united with phosphoric acid, and of phosphuret of lime or lime with phosphorus. The phosphat of lime, and the lime of the phosphuret were separated from the charcoal by solution in an acid and filtration, the remaining phosphorus was expelled by sublimation in a close vessel, and thus the charcoal was left pure. This in no way differed from common charcoal of wood, deflagrating with nitre, and yielding carbonic acid by the combustion. In the above experiment therefore a part of the phosphorus is oxygenated at the expence of the carbonic acid, and the decomposition of the latter appears to be effected by complicated affinities, namely by that of a part of the phosphorus for the oxygen of the carbonic acid, of another part of the phosphorus for the lime of the marble, and of the phosphoric acid (as soon as formed) also for the lime. Therefore the experiment succeeds better if the marble is first slightly calcined, that the surface may afford caustic lime for the phosphorus immediately to act upon. Phosphorus alone has less affinity for oxygen than charcoal has, otherwise it could not be produced by the simple heating of a mixture of phosphoric acid and charcoal.

A similar decomposition of carbonic acid was effected by Dr. Pearson with phosphorus and carbonat of soda, dried so as to expel all its water of crystallization, but not its carbonic acid. After heating red-hot for twenty minutes, the contents of the tube, which were partly melted to the glass, consisted of some undecomposed carbonat of soda, of phosphat of soda, and of a black powder, which when separated and analysed was found by many satisfactory trials to be pure charcoal. The quantity of it varied in different experiments from 32 to above 40 grains, from 200 grains of phosphorus and 800 of dry carbonated soda of the first materials.

Besides this entire decomposition of carbonic acid, a partial deoxygenation takes place in a great variety of instances, and the product is that kind of inflammable gas, the nature of which was long unknown and confounded with hydrogen and with hydro-carbonat gas, till the late experiments of Mr. Cruikshank, who first pointed out the true grounds of distinction, and has demonstrated the leading pro-

perties of this substance, intermediate between carbon and carbonic acid, to which agreeably to the present system of nomenclature, the name of *Gaseous Oxyd of Carbon*, or *Carbonous Oxyd* has very properly been given. This will be described in the next article, and to it may be referred many curious experiments on the decomposition of carbonic acid by electricity, performed by Priestley and others.

Besides the sources of carbonic acid already mentioned, it is produced in abundance by the action of nitrous acid on charcoal, and even on any substance containing a carbonous base. Thus Dr. Priestley^k procured it from alcohol and fuming nitrous acid. Under the article *NITROUS Acid*, it will be seen how far the action of this acid resembles the effects of common combustion, and hence it may generally be inferred that wherever carbonic acid would be generated by combustion, it would also be produced by the action of the nitrous acid on the combustible substance.

Many liquids absorb carbonic acid with great ease, such as alcohol, oil, &c. but it appears to be retained by no stronger adhesion than to water, and to be expelled by heat or other means, without having produced any sensible change. In like manner it mixes readily with every gas, but the only perceived effect is to render the air less able to maintain combustion (when at all so) and it does not seem to enter into any chemical union with any of the gasses. Ammoniacal gas must be excepted however, for with this it unites instantly, and a dense white cloud arises on mixture, which condenses into a solid *carbonat of ammonia*.

The affinity of carbonic acid with the alkalis, earths, and metals, is so weak that it is displaced in most instances by every other acid, the boracic perhaps excepted. Hence it is that a carbonated alkali will *effervesce* with any other acid, being expelled from the alkali in form of gas. This tendency to assume the gaseous form contributes much to the weakness of its affinity.

The order of the affinities of this acid are—barytes, strontian, lime, potash, soda, magnesia, and ammonia. With regard to the two last, their affinities are so nearly balanced that neither will entirely decompose the carbonat of the other substance, and the difference of a few degrees of temperature makes an essential alteration in the relative force of affinity.

The tendency of carbonic acid to quit all its combinations when strongly heated, renders it

^k Obs. on Air, vol. i. 134.

impossible to ascertain any of its affinities in the dry way.

CARBONOUS OXYD, or *Gaseous Oxyd of Carbon*.

The discovery of the characteristic properties of this gas, and of those chemical characters by which it is distinguished from *carburetted hydrogen*, *hydrocarbonate*, or *heavy inflammable air*, is entirely due to Mr. Cruikshank.

Till the researches of this chemist, it had always been objected by Dr. Priestley against Lavoisier's hypothesis of the constitution of fixed air (and always with a force of argument which only the wilfully blind theorist could overlook), that when charcoal, however dry, was distilled with scales of iron, or with the red oxyd of mercury, the product was not only carbonic acid, but a large quantity of a heavy inflammable air, which in some respects resembled the true carburetted hydrogen obtained by distilling moistened charcoal in a red heat, and was mistaken for it.

Carburetted hydrogen consists of hydrogen holding some carbon in solution, and were it produced by charcoal mixed with any metallic oxyd, the presence of the hydrogen could only be accounted for according to the antiphlogistic system, by supposing some water to remain united with the charcoal and to be decomposed during the distillation. But an inflammable gas is produced in great abundance, whatever be the heat to which the charcoal is previously exposed, and therefore were it really composed of hydrogen, the objection to the whole hypothesis founded on this experiment would be unanswerable.

Dr. Priestley in the above instance supposed the water to be a constituent part of the iron scales, and to be separated from it by the phlogiston of the charcoal uniting with and reviving the iron, but it is rendered more than probable by Mr. Cruikshank's discovery that water is not in the least necessary in the one or the other case to the production of that kind of inflammable gas produced by the above method, that this gas necessarily contains no hydrogen whatever, but has only a single combustible base, namely, carbon; and that with the same two ingredients as carbonic acid, it only differs from it in containing proportionally less oxygen, or in other words that it is an *oxyd of carbon*. Therefore it bears the same analogy to carbonic acid as the nitrous oxyd does to the nitric acid, the oxyd in each case not containing sufficient oxygen to impart the properties of an acid.

The experiments of Mr. Cruikshank^a have been repeated with much apparent accuracy by Messrs. Deformes and Clement,^b and the results of the two correspond very closely.

The gaseous oxyd of carbon may be procured by several methods, that is, either by the partial oxygenation of charcoal by distillation with metallic oxyds; or by the partial disoxygenation of carbonic acid by distilling the earthy carbonats with the filings of different metals; or by heating carbonic acid with charcoal, whereby the proportional quantity of the carbonous base is increased; or by the decomposition of carbonic acid by the electric spark.

Oxygenation of Charcoal by Metallic Oxyds.

The original experiment of Dr. Priestley is the following:^c Equal parts of the scales of iron and charcoal (each having previously been made very hot in separate vessels) were put into a glazed earthen retort and strongly heated. Instead of a product of *water*, which Dr. Priestley expected, a prodigious quantity of *air* came over, which on examination was found to consist of only one-tenth of fixed air, and the remainder was an *inflammable air of a very remarkable kind, being quite as heavy as common air*. "The reason of this," Dr. P. adds, "was very apparent when it was decomposed by dephlogisticated air, for the greater part of it was fixed air." The above two important properties of this kind of inflammable air, namely, its weight, and its almost total convertibility into carbonic acid when saturated with oxygen, are fully confirmed by subsequent experiments.

Repeating this experiment of Dr. Priestley, Mr. Cruikshank mixed some of the scales, or imperfect oxyd of iron separated in forging, with powdered charcoal (each being previously heated for an hour to redness before mixture) put them into a coated glass retort and heated gradually, receiving the gas in the pneumatic cistern over water. As soon as the retort was red, abundance of gas came over, which being examined at different periods was found in the beginning of the process to be composed of one part of carbonic acid and four of an inflammable gas (afterwards discovered to be the carbonous oxyd, with a small admixture of carburetted hydrogen :) after which, to the end of the process the proportion of the carbonous oxyd increased to about six-sevenths of the whole. Two ounces of the materials yielded many gallons of the gas.

The sublimed oxyd of zinc was next substituted to the iron scales and distilled with charcoal. Even before the retort became red, much

^a Phil. Journ. vol. v. 4to.

^b An. Chim. tom. 32.

^c Obs. on Air, vol. i. p. 298.

gas was given out, and on encreasing the heat it came over in torrents. It contained a much less proportion of carbonic acid than the last, and towards the end it consisted of pure inflammable gas. The absence of carbonic acid was known by its not rendering lime-water turbid. Part of the zinc was found in the metallic state sublimed in the neck of the retort.

In like manner the red oxyd of copper and charcoal gave by distillation, first, a mixture of carbonic acid with inflammable gas, and at last a gas purely inflammable. The copper was found reduced in small globules. Litharge and charcoal gave a similar result, and the lead was reduced. The oxyd of manganese previously partially deoxidated by heating to redness, was also mixed with charcoal and distilled, and gave the same products.

The distillation of charcoal and the sublimed oxyd of zinc was repeated by Deformes and Clement, with particular attention to the quantity of products from a given weight of the materials. The charcoal and zinc were first heated separately and examined. Common charcoal heated strongly gave a considerable quantity of an inflammable gas, and about $\frac{1}{10}$ of its weight of water. After an hour nothing farther came over, so that to ensure the perfect purity of the charcoal, it should be used hot from a crucible or other vessel in which it has been heated to a full red heat for about an hour. The oxyd of zinc gave nothing at all by being heated *per se*, so that it may at any time be considered as pure when previously freed from accidental moisture.

By experiment it was found that 1436 parts of zinc increased by calcination to 1748 of white sublimed oxyd, and hence it is inferred that 100 parts of the white oxyd consist of 82.15 of metal, and 17.84 of oxygen. Thirty grammes (463 grs. troy) of pure charcoal prepared as above, and still hot, were mixed with as much oxyd of zinc (equal parts having been found to be the proportions in which the carbonous oxyd is given with more ease than when less charcoal is used) and were put into a coated glass retort, with an adapter communicating with lime water, through which all the gaseous products passed. When first heated, a small portion of carbonic acid appeared, rendering the lime water turbid, but this effect soon ceased, and the gas was purely inflammable. In five hours all the production of gas had entirely stopped, and the entire products of the operation were as follows:

	grammes
Zinc sublimed in the retort	21.82
Charcoal remaining	26.60
Carbonic acid contained in the precipitated lime-water	0.07
Nine litres (16.9 wine pints) of inflammable gas, weighing	10.35
	58.84
Loss	1.16
	60.00

Disoxygenation of Carbonic acid.

Mr. Cruikshank having repeated an experiment of Priestley's to obtain an inflammable gas from carbonat of barytes, and the grey oxyd of iron, varied it in the following manner:

Equal parts of chalk (heated red hot previously for ten minutes) and iron filings were mixed and heated in a retort as before. Abundance of gas was given out, which consisted pretty uniformly of about one part of carbonic acid, and 5 parts of the inflammable gas.

An ounce of chalk, previously heated red for ten minutes, was mixed with as much zinc filings, and heated gradually in a coated glass retort. A little carbonic acid came over at first, but soon mixed with the carbonous oxyd, and when the contents were thoroughly red nothing but the inflammable gas came over, and in prodigious quantity. Examined at different periods of the distillation it was found perfectly inflammable, and free from carbonic acid. When cold, there was found in the neck of the retort some of the zinc sublimed and oxydated, below this some remaining metallic zinc, and at the bottom a crumbly mixture of unmetallic zinc with an imperfect lime.

Chalk with tin filings gave a similar result.

In the above three experiments the carbonic acid was united to an earthy base before distillation, and consequently it was exposed to the deoxydating effect of the metallic filings in its nascent state, or at the moment of its assuming the gaseous form, a state in which gaseous bodies are peculiarly susceptible of chemical change, frequently even when the very same substances refuse to act on each other after they have once acquired the state of gas. Mr. Cruikshank found however that even carbonic acid gas could be decomposed by the metals, though less perfectly. It was seen in the following way. A quantity of dry chalk was introduced into an iron retort, over which was rammed

some dry sand, and a stratum of iron filings over all. In this arrangement therefore the carbonic acid gas expelled from the chalk by heat would have to traverse a stratum of sand three inches thick before it would reach the iron filings. The gaseous products of the distillation were a quantity of undecomposed carbonic acid, together with a large proportion of the inflammable gas, and the iron filings were found considerably oxidated when taken out. The decomposition of carbonic acid by metals does therefore take place when the acid is in the gaseous form, but by no means so perfectly as in its nascent state. A similar decomposition was also effected by forcing the same carbonic acid gas successively backwards and forwards through an iron tube, the middle of which was full of iron filings, and was kept red hot by a small furnace beneath it. A bladder was tied to each extremity of the tube to receive the gas. By twenty times passing the gas slowly through the red-hot part of the tube two-thirds of it were converted into inflammable gas, and, by continuing the process, three-fourths.

Solution of Carbon in Carbonic Acid.

It is obvious that increasing the oxidable base of any substance already united with oxygen must have the same relative effect, as abstracting a portion of its oxygen; and this offers another mode of converting carbonic acid into the inflammable oxyd of carbon, which has been successfully practised by Messrs. Desormes and Clement.

Pelletier in his valuable experiments on barytes and strontian,^d discovered that the native carbonat of barytes, though scarcely calcinable *per se* in any fire, would readily part with its carbonic acid by calcination if previously rubbed to fine powder, and mixed with a small quantity of charcoal. The chemists above-mentioned on repeating this experiment with three parts of carbonat of barytes and one of charcoal obtained a large quantity of gas, composed of about $\frac{4}{5}$ of carbonic oxyd, and $\frac{1}{5}$ of carbonic acid, and in the retort the barytes was left quite caustic. Here, therefore, it is to be supposed that the carbonic acid is supersaturated with its own base, and thus rendered much more volatile than before.

A more direct combination of carbon with carbonic acid was also obtained by the same chemists, precisely with the same apparatus which Mr. Cruikshank had employed for passing the carbonic acid gas over red-hot iron, that is, with a tube filled in the middle with

charcoal, and with a bladder fastened to each extremity, which was kept alternately full or empty as the gas was pressed backwards and forwards through the tube. The first sensible effect produced on the calcined gas was a considerable dilatation, which was exclusive of the expansion by mere heat, and arose from the solution of a part of the heated charcoal in the gas as it passed over. After each experiment by far the greater part of the carbonic acid was found changed into the inflammable gaseous oxyd of carbon, the proportions of the former varying from about $\frac{1}{18}$ to $\frac{1}{36}$. The remaining charcoal taken out and weighed was found to have lost considerably, but the loss was greater when iron tubes were used than with those of glass or porcelain. Reckoning, therefore, the quantity of charcoal taken up by the carbonic acid in the different processes to be indicated by the loss of charcoal from the tubes, the composition of the gaseous oxyd into which the carbonic acid was converted was found to be, when iron tubes were used, about 48 of oxygen to 52 of carbon; and when porcelain or earthen tubes were employed it consisted of about 53 of oxygen to 47 of carbon.

It would appear from the result of several experiments that the inflammable gas is the purest when prepared from chalk and iron, or zinc filings; for when charcoal and the metallic oxyds are employed, or charcoal in any way, some admixture of a gas always appears, which causes the production of a portion of water when the whole is burnt with oxygen, and therefore must be hydrogen; but this is not the case with the inflammable air from chalk or carbonat of barytes and metallic filings. This if taken after the first portions have passed over and washed with lime-water or caustic alkali, to separate any carbonic acid it may contain, may be considered as pure *gaseous oxyd of carbon*, or *carbonous oxyd*, and its characteristic properties, (according to Cruikshank where not otherwise specified) are the following, to which may be added the distinctive marks whereby it is found to differ from carburetted hydrogen.

Carbonous oxyd is nearly of the same specific gravity as atmospheric air, being lighter than common air only in the proportion of 22 : to 23. Its specific gravity therefore will be about 1.177 (water being 1000. and common air 1.2308). On the other hand, the average weight of the true carburetted hydrogen is not more than half that of common air.

^d Memoires de Pelletier.

It suddenly destroys animal life. A bird put in a jar of it could not be withdrawn alive.^e

It is no way altered by being electrized *per se* for a length of time.^f In this it remarkably differs from carburetted hydrogen.

It burns in the open air with a quiet blue flame. When previously mixed with common air and kindled, it does not explode, but burns slowly; but mixed with oxygen it explodes by the electric spark, though not very violently. In this case the flame is red.

It is particularly by the products of combustion that this gas is distinguished from hydrogen, or any other known substance. The product of the burning of hydrogen with oxygen is water, of carburetted hydrogen is carbonic acid and water in different proportions; but the combustion of pure carbonous oxyd produces nothing but carbonic acid, and in very large quantity. This is well shewn in two methods. In one, let a small but constant jet of very pure gaseous oxyd be set fire to, and immediately introduced in a large glass balloon full of oxygen gas (with the same apparatus as is described under the similar combustion of hydrogen). It will then burn with increased brightness for a certain time, and be extinguished spontaneously, but without so great a diminution of gas as might be expected, the sides of the balloon will only be damp, but will not shew those copious drops of water trickling down as appear when hydrogen is burnt, and the contents of the balloon will consist altogether of carbonic acid gas, mixed with the unconsumed residue of oxygen. A second mode of conducting the combustion, is to mix the gaseous oxyd with oxygen in *Volta's Eudiometer*, and detonate the mixture by means of the electric spark. The explosion is not so violent as with hydrogen, or especially with some of the hydrocarbonates, and the residue is here also only carbonic acid together with any casual impurity of the oxygen.

The relative proportions of carbonous oxyd and oxygen requisite to mutual saturation, and the consequent production of carbonic acid, are the means of ascertaining the exact constituent parts of this inflammable gas. When 20 measures of the purest gaseous oxyd (that is, from chalk and iron filings) were mixed with 8 measures of oxygen and exploded, the whole was reduced to 18 or 19 measures, the whole of which was absorbed by lime-water, and was therefore carbonic acid. The weight of the latter also was found by other experiments to correspond as nearly with the sum of the weights

of the two before mixture as can well be expected in experiments of this kind, for 100 cubic inches of carbonous oxyd with 40 inches of oxygen produced 92 cubic inches of carbonic acid, and the weight of the first of these may be estimated at about 30 grains, of the second at 13.6, and of the third at 43.2 grains, and the sum of the two first differs from the third only by .4 of a grain.

From the above data, confirmed by other experiments of Mr. Cruikshank, it may be inferred that 100 parts (*by measure*) of gaseous oxyd of carbon require for saturation 40 measures of oxygen gas and produce by combustion about 92 measures of carbonic acid gas: or (*by weight*) that 100 grains of carbonous oxyd require $45\frac{1}{3}$ grains of oxygen, and are converted into 144 grains of carbonic acid. As this acid is the only substance that appears after the combustion (supposing the trifling production of water to arise from accidental impurity,) and as carbonic acid is only composed of carbon and oxygen, it must follow that the inflammable gas must either be pure carbon, or carbon already mixed with a certain portion of oxygen, but not sufficient for complete acidification. That the latter supposition is the truth is proved from a comparison of the known proportions of carbon and oxygen in carbonic acid with the quantity of oxygen necessary to be added to the inflammable gas for complete acidification. Carbonic acid is found by Lavoisier and other accurate chemists to be composed of about 28 (by weight) of carbon with 72 of oxygen; consequently 144 grains of carbonic acid (the product of the full oxygenation of 100 grains of the inflammable gas) contain 42.32 grains of carbon; and hence, as only carbonic acid is produced by the combustion, the remainder of the 100 grains, or 59.68 grains must be oxygen. Or, by another calculation, 144 grains of carbonic acid contain 72 per cent. or 103.68 grains of oxygen; but only 45.33 grains of oxygen were added to the inflammable gas to produce this carbonic acid, and consequently the difference between 103.68 and 45.33, or 58.35 grains of oxygen, were already contained in the gas, leaving 41.65 grains to complete the 100 grains of the gas, which is the carbon. So that the respective proportions of oxygen and carbon in 100 grains of the gaseous oxyd is by one estimation 59.68 of oxygen to 40.32 of carbon, and by the other it is 58.35 to 41.65, the trifling difference between the two arising from the small deficiency in the weight of the carbonic acid, compared to the sum of

^e Desormes and Clement.

^f Ibid.

the weights of the gaseous oxyd and of the oxygen consumed in the combustion.

Therefore we may reckon on an average that 100 grains of the carbonous oxyd obtained from the decomposition of the earthy carbonats with metallic substances in its purest possible state, unmixed with any hydrogen, to be composed of about 59 of oxygen and 41 of carbon.

In this calculation it may be observed, the inferences from Mr. Cruikshank's observations are corrected, by assuming more accurate proportions for the composition of carbonic acid, Mr. C. estimating only 20 per cent. of carbon in the acid, which is certainly much too low, as Lavoisier's proportions have been amply confirmed by other chemists.

The experiments of Deformes and Clement agree very closely with the above, these chemists deducing the composition of the gaseous oxyd to be in 100 grains, 58.4 of oxygen and 41.6 of carbon.

All the above calculations suppose a perfect uniformity in the composition of the gaseous oxyd, and the details of the various experiments will support this opinion tolerably well, considering the great variety in the quantities of the accidental impurities of the gas, both of hydrogen and of carbonic acid, and of carburetted hydrogen, excepting in the single instance of the carbonous oxyd produced by passing carbonic acid over red hot charcoal, where, as already mentioned, the quantity of carbon in the inflammable gas appears to be very variable, and to be much greater than when prepared in any other method. It is by no means improbable therefore that the carbonous oxyd may be supersaturated with carbon, part of which may perhaps be again separated by the action of affinities too weak to produce an entire decomposition of the oxyd.

A true combustion of the gaseous oxyd of carbon takes place when it is mixed with the oxymuriatic acid gas. If the latter be recently prepared and added to the carbonous gas in due proportion the whole mixture is converted into simple muriatic acid and carbonic acid, the oxygen having passed from the oxymuriatic acid to the carbonous oxyd and completed its acidification. Two measures of the carbonous oxyd were mixed with $2\frac{2}{3}$ measures^f of the oxymuriatic gas in a bottle which the mixture completely filled, the stopper was put in, and the neck plunged under mercury. After twenty-four hours the stopper was taken out under water, which rose immediately and occupied two-

thirds of the bottle. This first absorption was chiefly that of the muriatic acid. The residuum was then agitated with lime-water, and the whole was absorbed except about $\frac{1}{6}$ of a measure, which was azot, and doubtless an accidental impurity.

The oxyd of carbon when heated in contact with phosphorus dissolves a portion, and then burns with a pale yellow. The phosphorus is neither deposited nor acidified by long standing, or by being kept twenty-four hours over water.^g

The effect of hydrogen upon the carbonous oxyd is very striking. When equal parts of these gases are mixed together and passed through a glass tube made red-hot,^h a complete decomposition takes place, the gaseous oxyd deposits its charcoal on the surface of the tube, which, being nearly melting, causes it to adhere and to form a very brilliant uniform black enamel, whilst the oxygen of the gaseous oxyd by union with the hydrogen forms water, which is condensed at the further extremity of the tube. Some of the hydrogen passes through apparently unaltered.

The decomposition of carbonic acid gas by electricity, when in contact with mercury, or some other metallic body, and also by hydrogen, well illustrates the nature of the carbonous oxyd. Dr. Priestley was the first who found a change to take place in carbonic acid gas by taking the electric spark in it repeatedly for a considerable time.ⁱ Out of many experiments the following may be selected: in a small tube containing about $\frac{1}{15}$ of an ounce in measure filled with fixed air and standing over mercury, the electric spark was taken for an hour; after which the whole tube was clouded chiefly with a black matter, but at the bottom with a yellow substance like sulphur. Each of these substances was found to be part of the mercury by which the gas was confined and changed in the process. The air itself was a little enlarged, but the great alteration produced in it was that instead of being all absorbed by water, as pure fixed air is, about a fifth part remained insoluble in this fluid.

This curious experiment was repeated by Monge^k with great attention, and with similar results with others of importance. He found that when the electric spark is taken in fixed air, the volume of the gas sensibly increases, and that this enlargement goes on for a considerable time though the electrization is suspended: that it ceases after a certain time, and then the iron conductors (if this metal is used), are so completely

^e Cruikshank.

^f Deformes and Clement.

^g Ibid.

^h Experiments on air, vol. i. p. 112.

ⁱ Mem. de l'Acad. for 1786.

oxidated as to let fall scales of oxyd from their surface, evidently shewing a connexion between the change of the gas and that of the metal. He also found that after electrization that part of the gas which was not absorbed by caustic alkalis (and consequently was not carbonic acid) was highly inflammable, and when mixed with oxygen it exploded by the electric spark, as pure hydrogen does. This made him consider the residuary gas to be hydrogen, nor could the experiment be explained otherwise before the discovery of the gaseous oxyd of carbon, which by subsequent experiments this is found to be.

The elegant experiments of Theodore de Saussure have thrown further light upon this subject.¹ Electric sparks were taken for 18 hours in a glass tube containing 13 cubic inches of carbonic acid gas, pure and well dried, and confined by mercury. After electrization, much of the black oxyd of mercury described by Priestley was found, but the conductors, being copper, were not sensibly oxidated. A very slight dilatation amounting to no more than $\frac{1}{10}$ of a cubic inch was perceived. On throwing up caustic alkali only one cubic inch was absorbed, which was therefore carbonic acid. The residue was not hydrogen, but very pure gaseous oxyd of carbon; for when 100 parts of it were burnt with about one-third of oxygen gas no water was perceived, but the product was merely 77 parts of carbonic acid. No chemist has yet succeeded however in entirely converting carbonic acid into carbonous oxyd by electrization, but the quantity is obviously encreased in proportion to the continuance of the electric passage.

Carbonic acid gas was also found by the same ingenious chemist to be decomposed by hydrogen with the aid of the electric spark. In a long glass tube, $3\frac{3}{4}$ parts (in bulk) of pure carbonic acid mixed with as much hydrogen were electrified for 12 hours. A condensation took place, considerable at first, but towards the end, very slight. A number of fine drops of water were deposited on the upper part of the tube, and when the process was stopped, the bulk of the gaseous mixture was reduced from $7\frac{1}{2}$ to $4\frac{3}{4}$ parts, 1 of which was undecomposed carbonic acid, and the remaining $3\frac{3}{4}$ proved to be the gaseous oxyd of carbon, being inflammable, unabsorbed by water or alkali, and when burned with a third of oxygen gas, giving carbonic acid in the proportion of 70 measures to 100 of the inflammable gas. It also contained a small admixture of hydrogen. When the process was

finished in a day the metallic conductors were not oxidated, nor the mercury altered.

In the above experiment the hydrogen appears to unite with part of the oxygen of the carbonic acid to form the water that is condensed, whilst the carbonic acid by losing oxygen passes to the state of carbonous oxyd.

It appears from an experiment of Deformes and Clement^m that hydrogen which has been shewn to be so powerful an agent in decomposing both carbonic acid and carbonous oxyd, sometimes effects a complete disoxygenation of carbonic acid without sensibly passing into the intermediate state of carbonous oxyd. Hydrogen gas passed through a tube, containing the native carbonat of barytes heated red hot, is found to render the barytes caustic or pure, and sometimes to separate the carbonic acid as such, but at other times to bring over a quantity of a black carbonaceous powder, which is condensed in the water of the recipient, and which these chemists suppose to be the carbon of the decomposed carbonic acid.

A decomposition of carbonic acid by hydrogen, similar to that by electricity related by Saussure, also takes place when the mixed gasses are passed through a red-hot porcelain tube, and the gaseous oxyd is produced.

CARBURETTED HYDROGEN GAS.

Hydrocarbonate, or Heavy Inflammable Air. Gaz Hydrogène Carboné, Fr. Kohlenstoffhaltiges Wasserstoffgas, Germ.

The only definition that can apply to carburetted hydrogen as generally described, is, an inflammable gas considerably lighter than common air, not rendering lime-water turbid when shaken with it, and when burned with oxygen totally resolvable into carbonic acid and water.

It should be observed that many of the most important experiments on this gas were made previous to the discovery of the true nature of the carbonous oxyd, which discovery, whilst it assists in the explanation of several difficult phenomena in chemistry, throws some uncertainty on the results of former enquiries into the properties of carburetted hydrogen, and renders a further examination highly necessary.

Before it was suspected that carbon could exist in any other state of oxygenation than as carbonic acid, it might be inferred with tolerable (though not absolute) certainty that when any gas had been purified from carbonic acid by agitation with alkali or lime-water, if it furnished a fresh portion of carbonic acid after combustion with oxygen, the carbonous in-

¹ Jour. de Phys. tom. liv.

^m An. Chim. tom. xliii. p. 288.

ingredient existed in the state of pure carbon or charcoal. Therefore, as the only products of carburetted hydrogen when burnt with oxygen are carbonic acid and water, chemists generally satisfied themselves with estimating the quantity of carbon contained in the gas by taking about 28 per cent of the weight of carbonic acid produced, and set down the entire remainder as hydrogen. For example, if 100 cubic inches of any gas weighing 15 grains, were totally resolvable into carbonic acid and water by combustion with oxygen, and if by the combustion 54 cubic inches of carbonic acid weighing 25 grains were produced, the quantity of carbon originally contained in the gas would be reckoned to be 7 grains (being 28 per cent. of the weight of the carbonic acid) and the difference between 7 and 15, or 8 grains, would be considered as the weight of the hydrogen; or in other words the gas would be called a carburetted hydrogen, consisting of hydrogen holding carbon in solution, in the proportions of 8 (by weight) of the former, to 7 of the latter.

But it is obvious that this mode of estimating must be totally erroneous in the case (probably very frequent) of a mixture of gaseous oxyd of carbon and hydrogen gas, and hence no approach to analysis can be obtained without ascertaining both the water and the carbonic acid produced, and even then some uncertainty will occur, as will be presently mentioned.

So that it is possible, and by no means improbable, that there may exist three species of gasses, all of which have a claim to the title of *hydrocarbonat* or *carburetted hydrogen*, namely, 1st, hydrogen simply holding carbon in solution, or what corresponds with the original idea of a *hydrocarbonat*: 2nd. hydrogen mixed with gaseous oxyd of carbon: 3d. a mixture of the two former species, or hydrogen gas and gaseous oxyd of carbon, with an excess of carbon held in solution by one or both of these gasses. This last species therefore might also admit of some varieties, according to the solvent of the carbon.

Having noticed these difficulties, we proceed to the nature and properties of *hydrocarbonat*, as observed by different chemists.

Carburetted hydrogen gas is obtained in a great variety of ways, and with very considerable differences in specific gravity and proportion of ingredients. It is found native on the surface of stagnant waters, marshes, wet ditches, &c. through which, if examined closely, large bubbles will be seen to rise in hot weather, and may be increased at pleasure by stirring the bottom with a stick. In close still evenings if a candle is

held over the surface, flashes of blue lambent flame may sometimes be perceived spreading to a considerable distance. All that is not fabulous concerning the *ignis fatuus* is probably derived from this source. This species may be termed for distinction the carburetted hydrogen of marshes. In the purest form in which it can be collected it is usually mixed with about 20 per cent. of azot.

This gas is also given out very abundantly by almost every vegetable matter when subjected to a scorching heat sufficient to decompose them. When heated in close vessels much more *hydrocarbonat* is obtained than when burnt in the open air, the product in the latter case containing more carbonic acid. It would be endless to enumerate the vegetable sources of this gas, but some of the most convenient or usual methods of obtaining it pure may be mentioned.

The destructive distillation of any of the acetous salts has often been used. For this, let any quantity of dry acetite of potash be put into a retort and heated gradually. The salt soon melts in its water of crystallization, puffs up, and would boil over if the neck were not kept very hot as well as the bottom. The first products are, the air of the vessels and water, then when the acetous acid begins to be scorched, a large stream of gas begins and continues without interruption till the whole is fully red-hot, and little else remains in the retort but the alkali, in a carbonated state. Along with the gas much oil arises at different times, and condenses in the cool receiver. The gas, according to Dr. Higgins's very careful analysis,* after the first portions have passed over, consists of nothing but *hydrocarbonat* mixed with a variable portion of carbonic acid, which last may be separated by lime-water. The *hydrocarbonat* itself varies considerably. The first part is much heavier than the last (though still lighter than common air) and appears to hold in solution part of the oil, for on standing some time over water it becomes lighter, and is found to require less oxygen for saturation than before. The average specific gravity of the first and last gas mixed, which may be taken as an average of the whole, is to that of common air as 2 to 3.

Carburetted hydrogen is obtained in great purity by sending the vapour of inflammable vegetable matter through an earthen or glass tube passing through a furnace and kept red-hot in the middle. The vapour of camphor, ether, alcohol, and other inflammables treated in this way is converted into this gas, but a very great

* Experiments on Acetous Acid, &c. London, 1786.

difference takes place in the quantity of the gas, according to the degree of heat and other circumstances.

Another method of obtaining carburetted hydrogen is to put coal, wood, peat, &c. into any convenient vessel, an earthen or iron retort for example, and heat it slowly to redness.

Most animal inflammable substances, such as silk, fat, wax, and the like, yield this gas as freely as vegetable matters by a similar treatment. This was discovered by Berthollet, in his most masterly researches on the nature of animal matter and of ammonia; and as the gas in this case is not mixed with an unusual portion of azot, he sagaciously conjectured and afterwards fully proved that the azot, certainly contained in animal matters, went to constitute the ammonia which is always given off in the process.

Carburetted hydrogen (or at least a gas which gives carbonic acid and water by combustion with oxygen) is also generated in abundance when charcoal not previously dried is distilled *per se* in close vessels, and continues to be given off till it has been heated fully red-hot for about an hour, after which it ceases, and the charcoal, as mentioned under the two preceding articles, is now pure. A similar, though somewhat different process for obtaining the gas, is to enclose powdered charcoal in a tube passing through a furnace, to confine the charcoal loosely by a pellet of clay at each end of the tube, to heat it red hot, and in that situation to send through it the vapour of water kept boiling in a small retort attached to one end of the tube. Much carbonic acid gas is generated in this way, and when this is removed the remaining gas is inflammable.

Lastly, this gas may be obtained by the direct union of its constituent parts. If hydrogen gas is passed seven or eight times successively through an iron tube containing charcoal and heated red hot, a diminution of the bulk of the gas takes place, the hydrogen dissolves a portion of the charcoal, and then assumes the properties of carburetted hydrogen.^b

A most curious variety of hydrocarbonat gas was discovered by the associated Dutch chemists (Van Diëman, Troostwyck, and others), which is procured from ether or alcohol, and has the remarkable property of generating or depositing a heavy oil when in contact with the oxymuriatic gas. Hence it has been termed *oily carburetted hydrogen*, or *olefiant gas*. It appears to consist of carburetted hydrogen, supersaturated with a large portion of carbonous matter in some

unknown state of combination, and hence it requires a much greater proportion of oxygen for saturation, and also produces a much larger quantity of carbonic acid than the other hydrocarbonats: it is also much heavier. The mode and preparation of this singular gas, and its peculiar properties, will be separately described, but it may be added that according to Mr. W. Henry's experiments,^c the olefiant gas appears to be also contained partially in the hydrocarbonat from coal, from wax, and some other substances, and greatly to contribute to the quantity of light and heat, which these gasses give out, as well as to the proportion of carbonic acid.

Hydrocarbonat gas is singularly affected by the electric spark. Dr. Austin^d found that on taking the electric spark successively through this gas obtained from the acetite of potash and in considerable purity, the bulk of the gas enlarged after every shock; and by continuing it from 200 to 300 times it expanded to nearly twice its original dimensions. Examined after this expansion it was found however to be as inflammable as before, and by the test of lime-water no carbonic acid was generated. Dr. A. concludes that the enlargement can be only owing to the production of a quantity of hydrogen, and makes some inferences from the experiments, the most important of which are shewn to be improbable by the subsequent experiments of Mr. Henry on the same subject. Mr. H. fully shews^e that there is no *destruction* of carbon by this process, since the same quantity of carbonic acid is produced by oxygen after electrization of the carburetted hydrogen as before it. He likewise makes it appear probable that the water held in solution by the gas is the chief agent in this expansion, since when the gas is carefully dried by caustic alkali, no continuance of the electrization will enlarge it beyond one-sixth of its bulk, but when the contact of water is admitted, it expands to double its bulk as before. Perhaps the discovery of the carbonous oxyd will explain this fact. It is not improbable that the carbon of the gas may unite with the oxygen of the water and produce the gaseous carbonous oxyd, which would not give any precipitate with lime-water, and the bulk of the gas would be enlarged both by the carbonous oxyd and by the hydrogen of the water, and also by the expansion which the hydrogen of the hydrocarbonat would undergo after the carbon was separated from it: whilst the actual quantity of carbon remaining the same, as much carbonic acid would be generated by complete

^b Deformes & Clement. An. Ch. tom. 39. ^c Phil. Jour. 8vo. vol. ii. ^d Phil. Transf. vol. 80. ^e Ibid. vol. 87.

oxygenation as before electrization. It is not improbable that the affinities of carbon and hydrogen for oxygen are so nearly equal that either substance is able *partially* to decompose the compleat oxyd of the other. Thus we find (as mentioned in the last article) that when hydrogen and carbonic acid are together subjected to electricity, the carbonic acid is partially decomposed, and the product is carbonous oxyd and water; and on the other hand when water is decomposed by red-hot charcoal, a part of the product is also the carbonous oxyd.

The above expansion of carburetted hydrogen by electricity Mr. Henry has shewn not to depend on any oxydation of the contiguous metals, since it takes place in a close-stopped glass with conductors of gold, as well as with oxydable conductors, and over mercury.

All the hydrocarbonates are fatal to animal life, not merely (as appears) from its unsuitness to support life, but also from something positively noxious, since animals immersed in it die sooner than they would from the mere interruption of respiration.

This gas is scarcely, if at all, absorbed by water, but by long standing over it, it loses a portion of its combustible matter. This last however only applies to the hydrocarbonats that require at least their own bulk of oxygen to saturate them, and especially to that variety called the olefiant gas.

Simple carburetted hydrogen, when set fire to, burns at the surface in contact with the air with a blue flame with red edges, but when mixed with any of the olefiant gas the flame becomes much more brilliant, and resembling that of oil. Applied to the purposes of illumination, the hydrocarbonat from coal, from lamp oil, or from wax, conveyed through an Argand's lamp produces full as much light as when supplied with oil in the usual way,^f and these are also the gasses that appear to contain olefiant gas, and an excess of carbonous matter relatively

to their bulk. The brightness of the flame is much diminished when these gasses have been long kept over water, and hence for illumination they should be used as soon as prepared.

The combustion of carburetted hydrogen is much more brilliant in oxygen gas. If burnt in a vessel of oxygen in the way that *hydrogen* is burnt for the production of water (*described under that article*), the products may be collected, and are found to be simply carbonic acid and water.

If any of the hydrocarbonats is mixed with sufficient oxygen gas, and fired by the electric spark, or any other method, an explosion takes place more or less violent according to the quantity of carbonous matter condensed in the hydrocarbonat; and the remaining gas consists of carbonic acid, together with any unconsumed gas, or excess of oxygen, whilst the water condenses in drops on the sides of the jar. A single cubic inch of the mixed airs is generally as much as can be conveniently managed at a single explosion; and when any quantity of olefiant gas is present, even this quantity will endanger very thick glass jars. A very vivid red flame appears at the moment of explosion, and a great enlargement takes place in an instant, after which the bulk is suddenly reduced to much less than the original quantity. When the carbonic acid is absorbed, if the gasses have been properly proportioned, no gaseous residue is left, except accidental impurities.

The following table will shew the relative quantities of pure oxygen required to saturate 100 cubic inches of most of the known hydrocarbonats, but (as was mentioned in the beginning of this article) though the quantity of carbon contained in each gas may be readily estimated, no information is given as to the state of the carbon, that is, whether as simple carbon or carbonous oxyd, and therefore the actual quantity of hydrogen is equally unknown.

^f Henry, Phil. Jour.

TABLE.

One Hundred cubic inches of Inflammable Air (freed from Carbonic Acid).	Oxygen required for satura- tion.	Carbo- nic Acid produc'd	Pure Carbon.	Oxygen not employ'd for the Carbo- nic Acid.	Hydro- gen which the re- sidue of Oxygen would saturate.	Specific Gravity, Air being 1.000.	Authority.
	cub.inch.	cub.inch.	grains.	cub.inch.	cub.inch.		
from Marshes - - - -	150.	72.4 =	9.4	77.6	155.2		Berthollet
— Silk - - - - -	150.	88.4 =	11.5	61.6	123.2		Ditto
— Sugar - - - - -	100.	80. =	10.4	20.	40.		Ditto
— Charcoal - - - - -	138.1	59.5 =	7.74	78.6	157.2		Ditto
— D ^o in another experim ^t .	75.						Henry
— D ^o - - - - -	60.	35. =	4.55	25.	50.		Cruikshank
— D ^o - - - - -	66.	40. =	5.2	26.	52.	.478	Berthollet
— Olive Oil - - - - -	132.6	121. =	15.73	11.6	23.2		Henry
— Lamp Oil - - - - -	190.	124. =	16.12	66.	132.		Ditto
— Oak Wood - - - - -	54.	33. =	4.3	21.	42.		Ditto
— Dried Peat - - - - -	68.	43. =	5.6	25.	50.		Ditto
— Cannel Coal - - - - -	170.	100. =	13.	70.	140.		Ditto
— Wax - - - - -	220.	137. =	17.81	83.	166.		Ditto
— Olefiant Gas - - - - -	284.	179. =	23.27	105.	210.	.905	Ditto
— Camphor - - - - -	176.	116. =	15.08	60.	120.	.660	Cruikshank
— Ether - - - - -	170.	108. =	14.04	62.	124.	.660	Ditto
— Alcohol - - - - -	118.	75. =	9.75	43.	86.		Ditto
Hydrogen passed repeatedly over red-hot Charcoal -	49.	21. =	2.73	28.	56.		Deformes
from Ether - - - - -	equal for equal weights of the inflammable gasses					.709	Dutch Chemists
— Alcohol - - - - -						.436	
Gaseous Oxyd of Carbon -	40.	92. =	11.96			.968	Cruikshank

In the above table it is to be observed that Berthollet's estimates the quantity of oxygen required to form a given quantity of carbonic acid gas to be equal in *bulk* to the acid gas, which is nearly accurate; and also that two parts in *bulk* of hydrogen with one of oxygen are the proportions in which these substances unite when they form water. Hence taking the gas from sugar as an example, 100 measures of it require 100 measures of oxygen gas, 80 of which are supposed to go to form the 80 measures of carbonic acid actually produced, leaving a residue of 20 measures of oxygen, the whole of which is supposed to be employed in forming the water that appears after combustion, and which therefore must have required twice the bulk, or 40 measures, of hydrogen gas.

An inspection of the above table will shew so great a variety in the proportional results as to make it evident that no casual difference in the drying of the gasses, or accidental circumstances can account for it. For, taking only the two

first columns (these being the registers of actual experiments made by persons on whose skill and accuracy much reliance is to be placed) if there existed any uniform proportion between the carbonous and the hydrogenous ingredient in all the inflammable gasses, a similar proportion would be found between the respective quantities of oxygen necessary to saturation, and the carbonic acid produced; so that taking the gas from sugar as a general standard of comparison, the gas from marshes should yield 120 cubic inches instead of 72.4: the gas from silk 120 instead of 88.4: from charcoal, 110, instead of 59.5: from olive oil, 106, instead of 121: from lamp oil, 152, instead of 124: from wax, 176, instead of 137, &c. Still however some tolerable agreement is found between some of the hydro-carbonats that are obtained from some of the most inflammable of the vegetable substances or products as from coal, camphor, ether, &c. For taking the gas from coal as a standard of comparison, the gas from wax should yield by

oxygen 130, instead of 137: from camphor, 104, instead of 116: from ether, 100, instead of 108: and from alcohol, 69, instead of 75, which numbers correspond tolerably well.

Another circumstance to be particularly remarked is the very variable quantity of hydrogen which is inferred from the residues, a quantity which sometimes far exceeds and sometimes as far falls short of 100 cubic inches, the quantity employed, and which obviously shews some great error in the inferences drawn from the experiments. For, taking the gas from coal as an example, supposing it to answer to the general idea of a hydrocarbonat, that is, to consist simply of hydrogen gas holding carbon in solution, the oxygen required to saturate 100 measures is supposed to be divided into two portions, one of them amounting to 100 measures, going to form the carbonic acid, and the other amounting to 70 measures, entering into the composition of the water produced.

But 70 measures of oxygen require for this purpose 140 measures of hydrogen of the ordinary density, whereas the whole amount of the inflammable gas is only 100 measures, and therefore the hydrogen of which it is composed must be denser than common hydrogen at least in the proportion of 14 to 10, even neglecting the space occupied by the 13 grains of charcoal which the gas is also proved to contain. But if any of the carbon exists in the 100 measures of the inflammable gas in the state of the gaseous oxyd it must of course occupy more space than when as mere charcoal, and of course less space can be allowed to the hydrogen, and it must be still more condensed.

This condensation of hydrogen in the distilled products of vegetable inflammables is in itself highly probable, and indeed is inferred from the much higher specific gravity of carburetted

hydrogen than pure hydrogen; but if this condensation be allowed in some hydrocarbonats, an *opposite state* cannot be supposed in other hydrocarbonats, where the specific gravity is equally great. Yet this inference must follow in those cases where the quantity of hydrogen is inferred as above from the residue of oxygen, when it is less than the original bulk of the inflammable gas. Thus in the gas from sugar the estimated residue of oxygen is only 20 cubic inches, and therefore the hydrogen which it infers is only 40 inches, whereas the quantity of inflammable gas actually used was the inches, and therefore were this mode of computation just, this carburetted hydrogen ought to be *rarer* than common hydrogen, in the proportion of 4 to 10, a supposition obviously without foundation.

This part of the difficulty may be obviated by the very probable supposition that a part of the gas consists of the carbonous oxyd, which being mixed with carburetted hydrogen will give the same general appearances on combustion as simple carburetted hydrogen, and being much heavier, will account for part of the great specific gravity of this kind of inflammable air. Where the calculation is merely hypothetical, it may easily be so arranged as to supply by arbitrary quantities of charcoal and carbonous oxyd all the deficiencies of the estimated hydrogen. Of this the following will serve as an example.

Suppose as in the above instance 100 cubic inches of the gas from sugar require 100 inches of oxygen for saturation, and produce 80 cubic inches of carbonic acid (which are all the *facts* advanced) then the original 100 cubic inches might be thus distributed, without requiring either expansion or condensation of the hydrogen.

Inflammable Air from Sugar		Oxygen		Carbonic Acid	
	cub. inch.		cub. inch.		cub. inch.
Carbon ^s Oxyd	30	with	12.	produce	27.6
Hydrogen	70	—	35		Water
Charcoal 6.9			53		53.
	100		100		80.6

This mixture is of course quite arbitrary, and it is obvious that if a condensation of the hydrogen were supposed, the proportions might be varied; and it is likewise clear that no inflam-

mable gas yielding carbonic acid and water by combustion can be properly analyzed till the quantities both of the acid produced, and of the water are separately estimated.

As in the above table much confidence may be placed in M. Berthollet's *experiments*, it may be added that on repeating them several times no material variation was found in any, but in the gas from charcoal, the quality of which varied much according to the heat at which it was produced; and also that all the gasses were kept for some days over water, which is found materially to lessen the combustible matter of those hydrocarbonats that consume much oxygen, besides a small addition of azotic air from the water itself.

The oxymuriatic acid furnishes another very useful method of decomposing and analyzing all the hydrocarbonats. Mr. Cruikshank's accurate and beautiful experiments on this subject are highly instructive.^b The purest oxymuriatic acid gas is obtained by adding common muriatic acid to the oxymuriat of potash, and it should be used soon after it is obtained, for it in some degree loses its properties by keeping. The oxygen of this gas is so loosely combined with the muriatic acid that it quits it when any combustible is added, even without the assistance of the electric spark or any other ignited body, and when added to hydrocarbonat both the hydrogen and the carbon are oxydated, and the products are water and carbonic acid, or carbonous oxyd as in common combustion, together with the muriatic acid gas now freed from its oxygen and therefore copiously absorbed by water.

Pure hydrogen gas and the oxymuriatic gas were first tried: one measure of the former with 2 of the latter, mixed in a phial with a glass stopper and inverted over water, were suffered to remain 24 hours. The stopper being then withdrawn the whole gaseous contents were absorbed, and the water rushed into the phial filling it entirely except about $\frac{1}{10}$ of a measure which was azotic gas and doubtless an accidental impurity. From other experiments Mr. C. found that 2 measures of hydrogen required for perfect saturation no more than 2.3 measures of oxymuriatic gas, and hence as it is established that to produce water two measures of hydrogen are required to 1 measure of oxygen, it follows that the 2.3 measures of oxymuriatic gas contain 1 measure of disposable oxygen, or that portion which makes the difference between simple muriatic acid gas and oxymuriatic gas.

The different hydrocarbonats were then tried. Into a bottle filled with and inverted over water one measure of carburetted hydrogen from camphor well washed, was mixed with 2 of oxymuriatic gas. A slight cloud and trifling diminu-

tion were perceived, after which the stopper was put in and the materials suffered to remain together for twenty-four hours. When opened under water all the gas was absorbed except .43 of a measure, and lime water reduced it to .34. This residue was still inflammable, but burned with a lambent blue flame like the carbonous oxyd. It was proved to be chiefly carbonous oxyd by the large quantity of carbonic acid which it yielded when fired with oxygen, 2 parts of it with 1 of oxygen giving no less than 1.7 of carbonic acid.

In the above experiment the mutual decomposition of the oxymuriatic acid and the carburetted hydrogen produces no less than four new compounds, namely, common muriatic acid, by the loss of oxygen; water, by the union of the oxygen with the hydrogen; carbonous oxyd by the partial oxygenation of some of the carbon; and carbonic acid, by the complete oxygenation of the remainder.

On increasing the quantity of oxymuriatic acid to about four times the quantity of the carburetted hydrogen, the whole of the carbon was now found completely oxygenated, and every thing was absorbed by water or lime-water. The products were therefore only muriatic acid, carbonic acid, and water.

Mr. Cruikshank found a very considerable diminution in the quantity of carbonic acid produced, and of course of the proportion of the carbonaceous ingredient in the hydrocarbonats from camphor, ether, and alcohol, when they had been long kept over water or agitated with it. A similar difference in the quantity of combustible matter was observed by Dr. Higgins in the hydrocarbonat from acetite of pot-ash, which renders it highly probable that these hydrocarbonats hold in solution somewhat of an oily ethereal vapour, or a portion of the true olefiant gas, which water will absorb. Mr. C. brings the analogy of this ethereal oily part to the vapour of sulphuric ether. Dr. Priestley discovered that when ether is agitated with any gas it greatly expands it, and when shaken with a large portion of oxygen and ignited, a most violent explosion follows, and the products are water with carbonic acid gas. It appears to be the olefiant part of the hydrocarbonats which causes the slight diminution that some of them *immediately* experience when mixed with the oxymuriatic gas, for with pure olefiant gas the diminution is great and immediate, as will be afterwards mentioned.

These experiments were repeated by Mr. Cruik-

^b Ph. Jour. vol. v. 4to. p. 202.

shank, with the difference of producing the combustion immediately by ignition with the electric spark. A remarkable variety in the results was, a copious deposition of charcoal in fine powder after the explosion of the oxymuriatic and the carburetted hydrogen gasses, when the latter was not less than half the bulk of the former. In this case there was not sufficient oxymuriatic gas for saturation, but when more was used, no charcoal was deposited, but, as might be expected, a greater quantity of carbonic acid was produced. This separation of charcoal only took place with the hydrocarbons from camphor, ether, or alcohol, and with these this property was lost, by being kept some time over water.

Carburetted hydrogen is readily decomposed by sulphur, which unites with the hydrogen by stronger affinity, forming sulphuretted hydrogen gas, whilst the carbon is precipitated as a black footy powder.

Dr. Austin appears the first chemist who remarked this fact. His experiment is the following^h. Some sulphur and carburetted hydrogen were introduced into a glass retort, previously filled with, and inverted over mercury. Heat was applied till the sulphur sublimed. The melted sulphur soon became red, and as it sublimed it became quite black, and the retort was covered with a black crust. One-third of the air was by this process converted into hepatic air. The remaining two-thirds was carburetted hydrogen not sensibly altered. Sulphur and charcoal also when heated together in a glass retort, yield much hepatic (sulphuretted hydrogen) air.

The Dutch chemists already mentioned also found, that when carburetted hydrogen was passed over sulphur kept red-hot in the middle of an earthen tube, the products were sulphuretted hydrogen gas, and the remaining sulphur in the tube was blackened by the admixture of charcoal.

Carburetted hydrogen has never yet been applied to any common use out of the laboratory, but that which is procured by the distillation of coal, is obtained so cheaply, and gives so much light and heat when burnt in a proper apparatus, that it has been proposed to be employed for various purposes of illumination, to which it seems admirably adapted.

OLEFIANT GAS.

The discovery of this very singular species of carburetted hydrogen is due to some associated chemists of Amsterdam, (Van Deiman, Van

Troostwyck, Bondt, and Lawrenburgh) in their examination of the different products of the distillation of sulphuric acid and alcohol, in the preparation of *ether*.^k This gas appears in the common process when the distillation is nearly at an end, but where the only object is to obtain it and not the ether, the same proportions between the acid and alcohol should be used, as may be supposed to be left in the retort when the common distillation of ether is nearly at an end, that is, about four to one; therefore, mix gradually four parts of concentrated sulphuric acid with one of alcohol, and put them in small bottles used for procuring gasses. Much heat is given out on mixture, and the colour becomes brown, which gradually darkens to a perfect black when heat is applied. The gas in question begins to be given out at the moment of mixture, and proceeds so rapidly that the heat must be discontinued as soon as the materials are become quite black, or they would boil over out of the vessel.

The gas thus obtained is mixed with a little sulphureous acid which appears to be more or less in quantity according to the greater or less heat used. It is separated by washing the gas with water containing a little ammonia, after which the olefiant gas remains pure. No carbonic acid is ever found mixed with it, though this might be expected from the nature of the materials.

Pure olefiant gas thus prepared is nearly as heavy as common air, being lighter only in the proportion of 905 to 1000. Its smell is very fetid after the sulphureous acid and ethereous vapour are separated by washing. It burns with a dense flame like that of any of the oils or resins. Water neither absorbs nor alters it in any degree. None of the common re-agents, gasses, acids, or alkalies, produce any notable effect except the oxymuriatic acid, but the phenomena that occur with this acid are very curious.

Equal parts of olefiant gas and oxymuriatic acid gas being mixed together, a diminution of bulk takes place immediately, a visible vapour fills the vessel, heat is given out very sensible to the hand, and at the same time several drops of a thick pearl-coloured oil appear at the surface of the water over which the mixture is made, and immediately sinks to the bottom.

It is from this singular production of dense oil with the oxymuriatic acid, that this species of carburetted hydrogen has acquired the name of *olefiant*. When the oxymuriatic and olefiant gasses are mixed in about the proportion of four

^h Phil. Trans. vol. 80, p. 66.

^k Journ. de Phys. tom. 40.

to three, the whole is absorbed excepting accidental impurities, and is converted into oil and water, perhaps with a small portion of carbonic acid.

The oil generated in the process is heavier than water, whitish, and semi-transparent. By keeping, it becomes yellow and limpid. Its smell is highly fragrant and penetrating; its taste, somewhat sweet. It is partially soluble in water, imparting its peculiar smell. Caustic potash has no effect on the oil, but only separates the small portion of oxymuriatic acid adhering to it, and renders it more fragrant.

Olefiant gas appears from many experiments to have no other constituent parts than carbon and hydrogen, like the purer of the common hydrocarbonats, but contains a much larger portion of these ingredients, at least of the carbon.

It is decomposed by sulphur like the other hydrocarbonats.

The combustion of the olefiant gas offers some very curious experiments. When an argand lamp is supplied with it instead of oil, the flame exceeds every oil and other hydrocarbonat in beauty and brilliance.¹ When mixed with oxygen gas and detonated by the electric spark, the explosion is much more violent than with the common carburetted hydrogen. Mr. Henry found that only .03 of a cubic inch with .17 of oxygen shattered a strong glass tube; and a Volta's eudiometer $\frac{1}{4}$ of an inch thick, was burst with less than a cubic inch of the mixed gases. It is to be observed in all these experiments, that when only a small proportion of oxygen is used, much less than is required for saturation, the electric spark only kindles the mixture, but without any considerable explosion.

Another singular property of the olefiant gas is the copious deposition of charcoal when it is mixed with a small quantity of oxygen, or with the oxymuriatic acid, and kindled. When the mixture of the oxymuriatic and olefiant gases is made, two or three minutes elapse before the oil is entirely precipitated, but if this mixture is immediately set fire to, no oil is produced, but instead, so copious a deposition of charcoal takes place, that the whole vessel is obscured, as if it had been covered with lamp-black. No more of the acid gas should be used than is necessary to produce the combustion.

A similar deposition of carbon takes place when olefiant gas is mixed with just enough of oxygen to begin the combustion. The Dutch chemists^m found that it required two parts of oxygen to

$1\frac{1}{2}$ of the olefiant gas, and when this was set fire to by the electric spark, the vessel was entirely blackened with the precipitated carbon.

It should seem in the above experiments that the carbon is separated by the abstraction of a small portion of the hydrogen, and that this latter alone undergoes combustion with the oxygen when in small quantity, for on examining the residue no carbonic acid was produced. What is very remarkable, the residue, notwithstanding the deposition of charcoal, and the combustion of a portion of the original gas, actually expands to nearly double its former bulk, so that in making the experiment in a close bottle, when it is afterwards opened under water, gas rushes out from the vessel instead of water flowing in, as might have been expected. The residue is now no longer olefiant, but by combustion and other properties, it appears to be little else than a pure carburetted hydrogen of the common species.

The great excess of carbon condensed in olefiant gas is also shewn by the large quantity of oxygen required to saturate it, and the quantity of carbonic acid produced. Each of these (as expressed in the table) is much larger than for every other species of carburetted hydrogen.

Olefiant gas was procured by the Dutch chemists not only from alcohol and sulphuric acid, but by transmitting the vapour of alcohol or of ether through a red-hot earthen tube. The olefiant gas, however, appears not to be quite so pure, but to be mixed with common carburetted hydrogen. A very unaccountable circumstance occurred in these experiments. The earthen tube was a tobacco pipe, which yielded olefiant gas very readily, but on substituting a glass tube, the gas was no longer olefiant, but simple carburetted hydrogen. This difference did not depend on the porosity of the earthen tube, for when this latter was enclosed in a glass tube the gas was as before, olefiant; and even when the glass tube was filled with alumine, or with silex, and the vapour sent through, the same effect was produced, but when filled with lime, carbonat of lime, or magnesia, the gas was simple carburetted hydrogen.

The whole of this very interesting part of chemistry requires further examination, especially with a view to the formation of the oxyd of carbon, and by such enquiries we may hope to gain some knowledge of the great natural processes that are going on in the animal and vegetable kingdoms.

^m Ann. Chim. tom. 43. p. 127.

CARBONAT OF AMMONIA; or *Sal Volatile. Salt of Hartshorn.*

This, which is the best known of all the ammoniacal salts, is always prepared for general use by sublimation, and is found in the shops in white compact irregular lumps, somewhat resembling white sugar in appearance, and of a striated texture.

Carbonat of ammonia is a copious product of the distillation of all animal substances, almost without exception, but is actually prepared chiefly from the refuse part of horn, ivory, bone, &c. Being volatile in a moderate heat it soon rises in distillation, and is found dissolved in the natural watery and oily liquors which also distil from these substances. It is not from these however that this concrete salt is immediately prepared, but the impure ammoniacal oily liquor is first converted into the **MURIAT** of *Ammonia* (which see) from which the pure carbonat is prepared by the following process. Mix together two parts of dry chalk with one part of dry muriated ammonia in powder, put them into a proper subliming vessel, with the joinings carefully closed, and apply a gradual heat. A double decomposition now takes place, the carbonic acid of the chalk unites with the ammonia, and both rise together as a dense white fume, which concretes on the upper and cooler vessel, and gradually collects into a hard tough cake. The residue left in the heated vessel is the lime of the chalk, united to excess with the muriatic acid of the muriated ammonia, and is readily dissolved out by hot water. The sublimation should be continued till the lower vessel is red-hot. The same simple process (with a suitable apparatus) appears to be adopted for the preparation of this salt in the large way, as for experiment.

The carbonats of potash or soda will answer as well as chalk in the process, and less of them will suffice, but there can be no detriment to the product by using an excess of the carbonat which is to decompose the ammoniacal muriat.

The solid carbonat of ammonia thus prepared if it is dry, fresh made, or has been kept from the air, is very hard, tough, striated, white, and semitransparent. Its smell is extremely pungent, and to most persons agreeable, but when too copiously snuffed up it excoriates the nostrils. Its taste is saline and stimulating, but with a sense of coldness. It gives the usual tests of alkalies with vegetable colours. It is very soluble in water, and considerable cold is produced during the solution. At the heat of

55° water dissolves half its weight, and its own weight at 120°, but with constant loss by volatilization. When a solution of this salt is kept at a scalding heat, a part of the alkali is constantly flying off, and the solid salt thrown upon a hot shovel is totally volatile in dense white fumes. Even at the temperature of the air a constant loss is going on, as may readily be perceived both by the loss of weight, and by the penetrating ammoniacal scent with which a small portion of the salt exposed to the air will fill a large room.

It is extremely difficult to procure this salt in any tolerably regular crystalline form. Sometimes by sublimation small needled crystals are found clustered together, but confused. The common method of saturating water when hot, and crystallizing on cooling, will scarcely answer on account of the rapid volatilization of the salt from a hot solution.

Bergman succeeded in obtaining tolerably regular crystals^a, by taking a concentrated solution at a moderate temperature, saturating it with carbonic acid, and exposing it to intense cold. The crystals, though not quite regular, appeared to be octahedrons with truncated angles.

Carbonat of ammonia contains so much carbonic acid that it effervesces most vehemently with any of the acids.

This salt may be formed by a direct union of its two constituents in their gaseous form, which furnishes a very beautiful experiment. Fill a jar half full of carbonic acid gas over mercury, then throw up as much ammoniacal gas, also over mercury, and as soon as the gasses come together a very dense white cloud of precipitated carbonat of ammonia fills the jar, which is immediately followed by a total absorption of the gasses, so that if they are pure and properly proportioned, the mercury rises and fills the jar completely, leaving scarcely a visible residue. Some heat is given out by this sudden condensation.

As the ammonia is by much the lightest of the two gasses, to produce the condensation immediately it should be thrown up *after* the carbonic acid gas, and it will of course rise through this latter, mixing with it in its passage. If this order is reversed, the two gasses remain separate for a while by the difference of their specific gravities, and the white cloud and condensation begins from the point of contact of the two, and gradually spreads upwards and downwards.

The same experiment may be varied without

^a On the Aerial Acid Essays, vol. i.

requiring a mercurial apparatus, by throwing into any glass receiver (previously filled over water with carbonic acid gas), a stream of ammoniacal gas proceeding immediately from a mixture of quick lime and muriated ammonia in the manner described under the article *ammonia*. A beautiful stream of dense white vapour, which is the precipitated carbonat of ammonia, is seen to issue from the point where the tube conveying the ammonia touches the carbonic acid gas, and to fall down to the bottom of the receiver. At the same time an absorption takes place, and the water rises.

A very great variety is found in the relative proportions of carbonic acid, ammonia, and water, in this salt, even when the external appearance is nearly the same. Besides, a very considerable change takes place by exposure to air. If a quantity of the hardest and most pungent fresh carbonat of ammonia of the shops (which is semitransparent and of a striated or fibrous texture) be powdered and exposed to the air on a shallow plate in-doors or without, a very remarkable change begins to take place in a few minutes. A large portion of the salt evaporates, filling the room with the pungent ammoniacal odour, and the remainder becomes of an opake white, crumbly and very soft, and at last perfectly loses the whole of its smell and pungency.

This change is completed in a few hours, and the loss of weight is so considerable, that by standing for a night 100 grains will be reduced to from 48 to 60, more or less, according to the quality of the salt used.

The nature of this change and the composition of these two kinds of carbonated ammonia on an average calculation will appear by the following experiments.^a For distinction they may be termed the *pungent* and the *mild* carbonat of ammonia.

One hundred grains of the pungent salt, selected from a quantity recently made and very strong, supersaturated with dilute muriatic acid, with due precaution, were found to lose on an average about 54 grains of carbonic acid. Another 100 grains dissolved in water was added to muriated lime, allowing an excess of the latter. A considerable effervescence took place with the immediate loss of 12.5 grains of carbonic acid and a precipitation of carbonated lime, which, washed, dried, and gently ignited, weighed 89 grains. Of these 89 grains, according to the known proportions of this earthy salt, 49 grains were lime and 40 grains were carbonic acid, very nearly. Now as there was

a copious disengagement of carbonic acid, all the ammonia with which it was united must have passed to the muriatic acid of the decomposed muriated lime, and none of it volatilized. But 49 grains of lime were found to have been separated from the muriat, and the quantity of real muriatic acid requisite to saturate 49 grains of lime is 41.12 grains, according to the known composition of this salt. Therefore the quantity of ammonia contained in 100 grains of the pungent carbonat is that which is sufficient to convert 41.12 grains of muriatic acid into muriated ammonia, which, according to Kirwan, is about 25.8 grains. Hence 100 grains of the recent, or *pungent* ammoniacal carbonat may be reckoned to contain 54 grains of carbonic acid, 25.8 grains of pure ammonia, and 20.2 grains of water. It may be added that the quantity of carbonic acid lost by the effervescence on adding the carbonat of ammonia to the muriated lime is only 12.5, which added to the 40 grains contained in the carbonat makes up only 52.5 instead of 54, but the remaining quantity of $1\frac{1}{2}$ of carbonic acid may well be supposed to be entangled with the precipitate, and to be expelled during the washing and ignition.

The *mild* carbonat of ammonia was then in the same manner examined. It was perfectly without scent, and weighed only 49 per cent. of the pungent carbonat from which it had been procured by exposure to air for twenty-four hours. One hundred grains lost also by effervescence with muriatic acid on an average 54 grains of carbonic acid, so that the quantity of acid in equal weights of the two species of carbonats appears to be very equal. On adding another 100 grains to muriated lime a much more violent effervescence took place than in the former case, with an immediate loss of 26.5 grains. The carbonat of lime produced was only 58 grs. of which 26 were carbonic acid, and 32 grs. were lime; which, estimating as above, would require 26.9 grs. of muriatic acid, and would indicate about 16.2 grs. of pure ammonia in the 100 grs. of the mild carbonat. Hence it may be concluded, that 100 grs. of this species of carbonat contain on an average about 54 grs. of carbonic acid—16.2 grs. of ammonia—and 29.8 grs. of water.

The change that takes place therefore when the pungent carbonat is exposed to air, may be probably explained in the following way. All the ammonia exceeding that which is contained in the mild carbonat may be supposed to be above the true point of saturation, so that the

^a Own Experiments.

constituent parts may be arranged as follows :—

One hundred parts of the pungent carbonat of ammonia contain

Carbonic acid - - -	54	} 70.2
Ammonia - - -	16.2	
Ammonia in excess - - -	9.6	
Water - - -	20.2	
	100.0	

When this is reduced to 50 parts, and has become mild carbonat, all the excess of ammonia appears to be volatilized, and half of the saturated carbonat of ammonia, but less water in proportion; and when thus reduced, the 50 parts will therefore consist of about

Carbonic acid - - -	27	} 35.1
Ammonia - - -	8.1	
Water - - -	14.9	
	50.0	

It should be mentioned that, according to Mr. Davy, the proportion of ammonia in the sublimed carbonat, much depends on the heat used in the process, independent of any subsequent volatilization.^b

Carbonat of ammonia precipitates all the earths from their solutions in acids except magnesia, which it only partially decomposes, attended with particular circumstances, mentioned under *carbonat of magnesia*.

This salt is very soluble in all kinds of spirits, and as readily rises with them, as with water, in distillation. Advantage is taken of this property in preparing many of the ammoniacal spirits and compounds used in pharmacy.

The use of the carbonat of ammonia is chiefly medicinal. The common dry smelling salts for the pocket consist of this salt a little scented.

CARBONAT OF POTASH. *Kohlensaure gewächssalkali*, Germ. *Carbonate de Potasse*, Fr.

POTASH. PEARLASH. *Gemeine Pottasche*. *Calcinierte Pottasche*, Germ. *Salin. Potasse*, Fr.

SALT OF TARTAR. *Weinsteinlaugensalz*, Germ. *Sel de Tartre*, Fr.

In this article we shall first treat of the method of procuring the vegetable fixed alkali, and the different forms under which it appears in commerce and domestic use, and shall then notice the preparation and characters of that neutral salt properly called, according to the modern chemical nomenclature, *Carbonat of Potash*.

The vegetable fixed alkali was so named by the chemists of the last and former ages, be-

cause it was procured in large quantities from vegetable substances, and was in no case supposed to be of mineral origin. From certain late analyses, however, by Klaproth and other able chemists, it has been discovered to enter, as an essential ingredient, into the composition of leucite, lepidolite, and a few other minerals, which are by none suspected of deriving their origin from organized bodies. But though the existence of potash in a mineral state has been thus demonstrated, yet it is so small in quantity, and so difficultly procurable, that all the vast supplies of this substance which civilized life requires, have as yet been entirely obtained from the combustion of vegetables.

If the woody or annual stems of vegetables, that have grown in soils unimpregnated with common salt, after being sufficiently dried are set fire to, the watery, the resinous, the oily, the acid and carbonaceous portions are volatilized and dissipated in a state of more or less complete decomposition, and there remains behind a reddish or whitish powder, called *ash* or *ashes*; consisting chiefly of the earthy and metallic ingredients of the vegetables, together with a variable proportion of sub-carbonat of potash. By lixiviation with hot or cold water the alkaline part is dissolved out, and this solution when boiled down to dryness leaves behind a dark brown saline mass, consisting of the carbonated potash, coloured by a small portion of vegetable inflammable matter; and in this state it is known in the English market by the name of *potash*. Calcination at a moderate red heat completely burns off the colouring particles, and the salt becomes of a spongy texture, and beautiful bluish white tinge, and is then called *pearlash*. Such is in general the process by which the vegetable fixed alkali is separated from the substances with which it is combined by nature, and prepared for use. We shall now proceed to describe more at large the different methods of extracting this salt, together with the precautions that are necessary to secure the greatest success.

The simplest and rudest preparation of potash is called *ash-balls* in England, and *weed-ash* in Ireland. It cannot be said properly speaking to be an article of commerce, although a considerable quantity is annually made by the peasantry of both countries, and disposed of among the neighbouring farmers and bleachers. The vegetable from which this impure alkali is produced is the common fern or brakes (*Pteris aquilina* Lin.) Many rough and heathy districts are entirely covered with this plant, which

^b Researches, p. 75.

when it has attained its full growth, (which happens about the middle of July) is cut down, and after being half-dried in the open air, is gathered into small heaps and kindled. The combustion proceeds slowly, being accompanied by a smothering smoke and little or no flame, till the whole is reduced to a reddish grey ash: this being carefully collected is sprinkled with a little water, and then moulded by hand into balls from three to four inches in diameter, which when they have acquired a certain hardness and solidity by drying in the sun, are ready for sale. In Ireland, thistles, docks and weeds of all kinds are mixed with the fern, and the ashes are disposed of in their loose pulverulent state without any further preparation. According to Dr. Home fern-ashes contain about $\frac{1}{3}$ of their weight of salt, consisting principally of sub-carbonat and sulphat of potash. 1000 parts of the plant cut in August, and thoroughly dried, afford 36.46 of ashes, from which are obtained by lixiviation 4.25 of salt. The common Irish weed ashes have been analyzed by Mr. Kirwan; and when deprived of their water by a red heat appear to contain 1 part of salt for $3\frac{1}{2}$ parts of ash; of this the free alkaline portion however, as deduced from the quantity of alum decomposed by the lixivium, amounted only to $\frac{1}{2}$ of the whole.*

The *potash* of commerce, or *black potash*, as it is also called, is universally procured from the combustion of wood; and therefore its preparation can only be undertaken with success in those uncleared countries in which are vast natural forests, and where from the badness of roads, and imperfection of water communication, the value of timber is no more than that of the labour employed in felling it. The only districts in Europe in which any considerable quantity of potash is made, are the mountainous forests of Germany, and the extensive woodland tracts of Poland and Russia. The British market however is principally supplied from the United States of North America; a country in which from its rapid increase in population there is a constant demand for cleared land for the purpose of cultivation, and therefore timber is looked upon rather as an incumbrance, than as contributing either to the beauty or value of the ground on which it stands.

The most wasteful method of manufacturing potash is that practised by the Americans, partly on account of the ignorance of the people by whom it is prepared, but principally

because this employment is carried on rather as subsidiary to clearing the ground for agriculture than on its own account. The wood as soon as it is sufficiently dry to burn is collected into large piles and reduced to ashes: these ashes are then put into a wooden cistern, with a plug at the bottom of one of the sides, and a quantity of water sufficient to make a strong lixivium is added: after standing for an hour or two the plug is withdrawn, and the water holding the potash in solution runs clear out, leaving the earthy part still impregnated with alkali in the cistern. This solution is then evaporated to dryness in iron pans, and hastily fused into compact reddish brown masses of semi-caustic potash, in which state it is fit for the market.

In Germany, where potash is prepared on its own account, and where a greater degree of intelligence and economy is practised, the general method of proceeding is the same as that just mentioned, but with such variations as, though seemingly of little consequence, materially augment the produce of alkali. Care is taken to select such kinds of wood as are the richest in potash; the combustion is slower, and of course the temperature lower, in consequence of which but little is lost by volatilization; the lixiviations of the ashes are also judiciously repeated till the whole of the alkali is extracted.

The common Russian potash is the impurest of all, containing nearly one half its weight of earth, and is thus prepared. A large pit is dug, into which are thrown burning brands and the smaller extremities of the branches, and when the whole is well kindled the pit is filled up with logs and other large pieces, which at length, though very slowly, are reduced to ashes. The coarser part of the ashes is then separated by sifting from the finer; all the alkali that it contains is procured by lixiviation; and this liquor is mixed with the remainder of the ashes and worked together into a kind of paste. A pile is then built of alternate strata of wood and this paste, and being set fire to the whole is again reduced to ashes. This process is repeated several times till the ashes begin to clot and become hard: the most compact pieces being then selected, are packed up for sale without any further preparation; the rest are lixiviated and boiled down to dryness in the usual manner.

In some parts of Germany potash is made from the empyreumatic acid produced from wood while burning into charcoal. By means of wide tubes of plate iron or copper, the acid

* Irish Transactions.

and oil which would otherwise be dissipated in the air, are collected; the watery acid part being then separated from the other is evaporated to dryness, and the residuum by calcination affords an ash extremely rich in alkali.

Potash is converted into a much purer alkaline salt called *pearl-ash*, by calcination: for this purpose, the potash broken into moderately small pieces, is spread on the floor of a reverberatory furnace, and being then kept red-hot, but not melted, for an hour or two, stirring it occasionally with an iron rake, all the carbonaceous and colouring particles are burnt out, and there remains behind a dry porous and considerably caustic salt, extremely deliquescent, and from its bluish white colour called *pearlash*.

It has been thought of consequence in an economical point of view to discover the pro-

portion of potash afforded by different vegetables, and many analyses have been made for this purpose. They are however for the most part unsatisfactory, as they indicate only the quantity of soluble saline ingredients without distinguishing the carbonated potash from the sulphat and muriat of potash with which it is always mixed. The most remarkable and interesting results will be found in the following table, part of which were ascertained by a Committee of the Academy of Sciences at Paris, and the rest by the chemists whose names are subjoined. 100 parts of each different species, being previously thoroughly dried, were burned by an open fire to ashes, which, after being weighed, were accurately lixiviated till all their saline contents were extracted.

100 parts.	Ashes	Salt	Salt from 100 parts of Ashes	
Fumitory	21.9	7.9	36.	Wiegleb
Wormwood	9.74	7.3	74.8	Ditto
Common Nettle	10.67	2.5	23.4	Pertuis
Sow Thistle (<i>Sonchus arvens.</i>)	10.5	1.96	18.6	Ditto
Fern	5.	0.62	12.5	Ditto
Ditto	3.64	0.42	11.6	Home
Stalks of Maize	8.86	1.75	19.7	
Ditto Sunflower	5.72	2.	34.9	
Buckwheat			33.3	Vauquelin
Vine branches	3.4	0.55	16.2	
Heath			11.5	Wildenheim
Foxglove (<i>digitalis purpurea</i>)			33.	Leipfic econ. Soc.
Celandine (<i>Chelidonium maj.</i>)			25.	Ditto
Nightshade (<i>atropa bellad.</i>)			27.	Ditto
Boxwood	2.9	0.22	7.8	
Sallow	2.8	0.28	10.2	
Elm	2.3	0.39	16.6	
Oak	1.3	0.15	11.1	
Beech	0.58	0.12	21.9	
Aspen	1.22	0.07	6.1	
Fir	0.34	0.04	13.2	

Upon a cursory inspection of this table, it appears that the succulent herbaceous plants afford a prodigiously greater proportion both of ashes and salt than the shrubby and ligneous ones: it is however to be observed, that they were all reduced to a state of perfect dryness before being weighed, a circumstance which will in a considerable degree account for the apparently greater quantity of salt contained in the succulent vegetables; for while the different kinds of wood will not lose more than $\frac{1}{3}$ or even

$\frac{1}{5}$ of their weight in drying, fumitory will probably lose $\frac{9}{10}$ or even more. It is not likely therefore that it can be ever worth while, as some speculators have proposed, to be at the expence of cultivating fumitory and wormwood, for the sake of the potash contained in their ashes.

It has been a subject of enquiry among chemists whether the potash that is obtained by the combustion of vegetables is formed by this process, or only disengaged by the decomposition of

those acids and other vegetable principles with which it was before united. The former of these opinions was adopted by Macquer and many of the eminent chemists that were contemporary with him, but of late the latter opinion has been rather gaining ground. The principal arguments by which Macquer supports his theory are the following^d. 1st. When vegetables, capable of furnishing much alkali by combustion, are decomposed in any other way, no other saline products are obtained but liquid and concrete acids. 2d. When vegetables are deprived of part of their acid by distillation the produce of alkali is proportionately diminished. 3d. The concrete acids, as tartar, are changed into alkali merely by combustion. 4th. Plants that yield little or no acid in distillation are found after combustion to afford little alkali. 5th. Plants, which when burnt without any previous alteration, yield much alkali, if burnt after undergoing compleat putrefaction, afford no alkali.

In opposition however to these arguments it may be observed, 1st. That the native concrete oxalic, and tartareous acids have been proved by modern chemists to be acidulæ, or in other words to contain potash, though not to full saturation of the acid; and therefore when these are burnt no conversion of acid into alkali takes place, but the acid being volatilized and decomposed, the alkali which was before masked by an excess of acid now exhibits itself with its usual characters. 2d. Nitre compleatly formed has been discovered in borragé and some other vegetables, therefore the existence of potash, the alkaline base of this salt, is also necessarily demonstrated. 3d. Vauquelin has shown that the sap of trees contains acetite of potash. 4th. The reason why vegetables after putrefaction yield no alkali is that their texture being broken up by this process, the water which drains through the mass dissolves and carries off all the alkali which they at first contained. This is manifest from the experiments of Mr. Birch,^e who, by evaporating and calcining 24 wine-pipes, or 3024 gallons, of dunghill water, procured 1048 lbs. of good marketable potash. We may therefore conclude that the potash obtained by lixiviation of vegetable ashes pre-existed in the plants themselves: whether this alkali is formed during the process of vegetation, or is only imbibed from the earth by the roots, is not as yet determined.

The varieties of pot and pearlash which are

found in the market would no doubt on analysis afford very different results, especially with regard to the proportions of earthy matter, of water, and of carbonic acid; it is not therefore perhaps much to be regretted that we possess no very accurate analysis of any of them. The only one on which any reliance can be placed is of Dantzic pearlash by Mr. Kirwan,^f in which are contained about

60.3	potash
22.4	carbonic acid
7.2	water
8.7	fulphated potash
0.7	muriated ditto
0.7	earth

100.0

But if the analysis of any particular sample is of little consequence generally speaking, yet it is of considerable importance both to the manufacturer and chemist, to be in possession of a compendious and accurate mode of ascertaining the contents of the various kinds of pot and pearlash, in order to make advantageous purchases of articles, in the intrinsic worth of which there is so much difference.

Mr. Kirwan's method of calculating the proportion of real alkali, in a given lixivium, from the quantity of precipitate which it throws down from a solution of alum, is by no means to be depended on; for in the first place the filix and alumine which the lixivium holds in solution, are precipitated together with the earth of alum; and in the second place so much depends on the degree of washing and calcination which the precipitate is made to undergo, that from equal quantities of alum it is scarcely possible to obtain equal weights of earth. Upon the whole therefore perhaps the best mode of proceeding is as follows.

1st. Prepare a diluted sulphuric acid by mixing the concentrated acid, called oil of vitriol, with three times its bulk of distilled water. Then test it by taking 100 grains of the diluted acid, and adding muriat of barytes as long as any precipitate falls down. The fulphat of barytes thus prepared when washed with cold water, and dried at a low red heat, contains 33.3 per cent. of sulphuric acid, hence the real acid in any quantity of the diluted acid is readily ascertained.

2d. Pulverize 500 grains of the alkali under examination, and digest it in warm water, adding fresh portions of this fluid as long as any

^d Macquer's Chem. Dic. art. Alkali.

^e Phil. trans. for 1780, p. 345.

^f Exam'n. of the alkaline substances used in bleaching.

thing is dissolved. Then put all the solutions together, and drop in the tested sulphuric acid from a vial containing a known weight of the same, till the slightest possible excess of acid is indicated by a paper tinged with litmus. After this, heat the mixture to expel all the carbonic acid, and if the liquor changes turmeric paper add a few drops more of sulphuric acid till it ceases to show an excess of alkali. Now weigh the vial of sulphuric acid, and thus ascertain how much has been expended in saturating the alkali, and for every 100 parts of real acid (as previously determined by muriat of barytes) thus employed, set down 121.2 of pure potash. The alkali being the part which gives value to the whole, this is all the examination which in ordinary cases is required, but if the analysis is to be carried further—

3d. Take 500 grains more of the alkali, dissolve it in boiling water and pour the solution into a flask; then place the flask and a vial containing from two to three ounces of pure nitric acid into one scale of an accurate balance and equipoise them. Afterwards add the acid by degrees to the alkali as long as any effervescence takes place, and the loss of weight indicates the amount of carbonic acid. The solution will now probably crystallize, a sufficient quantity of water is therefore to be added in order to dissolve the crystals, and nitrat of barytes is to be dropped in so long as any precipitate takes place. 100 parts of the dried sulphat of barytes thus procured indicate 73.6 of sulphated potash. This being removed, add to the clear liquor nitrat of silver till it ceases to be decomposed. 100 parts of muriated silver show 41.34 of muriated potash. Thus the saline contents are all of them ascertained, viz. potash, carbonic acid, sulphat and muriat of potash. The earthy part is shown in the insoluble residue, No. 2, and in the precipitate which falls down on boiling the alkaline liquor after its saturation with sulphuric acid. If any sulphur is contained in the alkali, as is the case with the black potash, this will fall down together with the earth upon saturation with sulphuric acid, and is separated from the earth by a red heat.

Having now treated of the impure subcarbonats of potash we shall conclude this article with an account of the purer subcarbonats and the perfect carbonat of potash.

The most important of the purer subcarbonats is *salt of tartar*, which is prepared in the wine countries in considerable quantity, and is the kind generally used in medicine. The lees of wine and the tartar that is deposited on the sides

of the casks are put into small bags about a foot long, and subjected to a strong pressure in order to squeeze out all the wine which is disposed of to the brandy distillers; the contents of the bags being carefully taken out, without breaking, form masses like loaves, which are dried in the sun, and then piled up in a furnace with alternate strata of charcoal. The fire being kindled, and the draft properly regulated, the acid and inflammable matter of the tartar is burned off without fusing the alkaline part; when the process therefore is finished, the loaves remain of nearly the same size as before, but very porous and perfectly white. Being then broken into pieces they are dissolved in hot water, and the clear lixivium being evaporated to dryness and then slightly calcined is fit for sale. $2\frac{1}{2}$ parts of tartar yield one of salt of tartar.

A more expeditious but less economical way of procuring salt of tartar is to mix equal parts of crude tartar and nitre, and project the mixture into a red hot crucible. A rapid deflagration takes place, the nitric acid, and the combustible parts of the tartar mutually decompose each other, and there remains behind the alkaline base of each united with some carbonic acid. This preparation is called *white flux*, *nitre fixed by tartar*, *extemporaneous potash*.

The perfectly saturated carbonat of potash has not been known to chemists longer than the time of Bergman. It may be prepared in two ways: the first, which was discovered by Berthollet, is as follows. Take equal parts of salt of tartar and carbonat of ammonia, dissolve the whole in warm water, then pour the solution into a retort, and proceed to slow distillation; the potash having a stronger affinity for carbonic acid than ammonia has, deprives this latter of its acid, and in consequence ammoniacal vapour is given out in great quantity: when this ceases, the contents of the retort are to be poured into a convenient vessel, where, by refrigeration, a copious deposition of crystallized carbonat of potash will take place.

The other method, and that which is generally practised, is to put a solution of salt of tartar into an apparatus for impregnating water with carbonic acid, and then to throw in this acid till the alkali is quite saturated, and refuses to take up any more; on opening the barrel, it will be found lined with large crystals of carbonated potash.

The form of its crystals is that of a tetrahedral rhomboid with dihedral summits. It requires for its solution about 4 parts by weight of cold water, but dissolves in $\frac{1}{2}$ of its weight

of boiling water: a considerable absorption of caloric takes place during its solution. It is hardly at all soluble in cold alcohol, and requires above 200 parts of this fluid when boiling for its compleat solution.

It has been analysed both by Bergman and Pelletier: each of these chemists agrees in the proportion of alkali, but they differ materially in their estimation of the water, and carbonic acid.

Bergman	Pelletier
48	48 potash
20	43 carbonic acid
32	9 water
100	100

The taste of this salt is cool and fresh with hardly any of the alkaline flavour; on which account, and because it is fully saturated with carbonic acid, it is greatly preferable to common salt of tartar in the composition of effervescing draughts, and for other medical purposes. It is neither efflorescent nor deliquescent in the air. It is decomposable with abstraction of its acid by barytes, and lime, and strontian, and with abstraction of its alkali by all the mineral, and almost all the vegetable acids.

The uses of potash are innumerable. It is consumed in the greatest quantities by soap-boilers, bleachers, and glass-makers. In the laboratory it is in constant and indispensable service.

CARBONAT OF SODA. *Carbonate de Soude*, Fr. *Kohlensaure mineralische gewachssalkali*, Germ.

KELP. *Soude de Varech*, Fr. **BARILLA.** **NATRON.**

This salt is found to exist both in the mineral and vegetable kingdoms of nature. When mineral, it is met with either dissolved in the water of certain hot springs, as those of Carlsbad in Bohemia, and Rykum in Iceland, or of certain lakes, as the natron lakes of Egypt and Hungary; or it occurs in the state of a solid salt as the fossil natron of Tripoli, called Trona.—In the vegetable kingdom carbonat of soda has been proved to exist ready formed in the *salsola* soda, and in all probability is contained in all those succulent saline plants that grow in places impregnated with muriat of soda. In order to supply the vast demands for carbonated soda it is procured from both the sources above-mentioned by processes which we shall now relate, beginning with the mineral soda.

There are two varieties of mineral soda, the striated and the compact. The striated has hitherto been procured only from Africa. It is found in the province of Sukena, between Tripoli and Fezzan, forming a very thin stratum just below the surface of the soil: it is of a striated crystalline texture resembling striated gypsum, and from some specimens described by Dr. D. Monro,^a the stratum (which does not exceed an inch in thickness) is in contact both above and below with common salt. From the account of Mr. Bagge, however, it appears that the natron district is at a considerable distance from the salt mines, and the analysis of this substance by Klaproth exhibits no trace of muriatic acid in its composition. It is collected to the amount of some hundred tons annually, but scarcely ever finds its way to the European markets. It is characteristic of the striated soda that its crystals instead of efflorescing as this salt usually does, remain permanent in the air, a circumstance that is to be attributed to the comparatively small quantity of water of crystallization that it contains, and to the compleat saturation of its alkaline base by carbonic acid. Common carbonated soda consists of

22 soda
16 carbonic acid
62 water

100

whereas the trona, according to an accurate analysis of it by Klaproth,^b consists of

37 soda
38 carbonic acid
22.5 water
2.5 sulphated soda

100.0

The compact mineral soda or natron, although contained in the waters of several springs and lakes, is procured in quantity only from Egypt and Hungary. The Egyptian natron lakes, six in number, are situated in a barren valley, called Bahr-bela-ma, about thirty miles westward of the Delta. During three months in the year they are supplied with water from copious springs that burst out from the western side of the valley, but as they receive no water during the rest of the year some of the smaller and shallowest ones are generally dried up during the summer. The soil consists of calcareous rock mixed with gypsum, and for the most part

^a Phil. Trans. lxi. p. 567

^b Analyt. Ess. ii. p. 63.

covered over with sand. The salts contained in these lakes are muriat and carbonat of soda, and it is remarkable that the proportions of these two not only vary in the different lakes but in different parts of the same lake, so much so that the crystalline deposits at that extremity of the lake which is the shallowest, and in which rushes grow, are principally carbonat of soda, while those formed at the opposite extremity are almost entirely common salt. The lakes are surrounded with a band, some yards in breadth, of saline efflorescences, but the principal accumulations of salt are in the water at a little distance from the bank. The natron appears to be formed by the slow mutual decomposition of the lime-stone and common salt assisted by the rushes, up the sides of which the natron rises by the force of efflorescence: when the rushes thus incrustated are broken by the wind, the soda on their surface assumes its proper quantity of water, and forms a confusedly crystallized stratum of the thickness of from one to twelve inches, according as the weather and other circumstances are more or less favourable to its production. In most of the lakes the deposition of natron takes place only at certain periods, in the intervals of which crystals of common salt are produced so that the saline masses which are dug out, especially in those parts that have been long undisturbed, present alternate strata of muriat and carbonat of soda. The efflorescences on the shore of the lakes, and the detached crystals that form in abundance at the water's edge are mixed with a much smaller quantity of common salt than the more compact masses, these latter however being rather more convenient to carry, and being procured with least trouble are constantly preferred, and as no subsequent purification is had recourse to, the natron of Egypt is by no means so valuable as it might easily be made. It is chiefly exported to Greece and other parts of Turkey, to Venice, to France, and Britain.^c

The natron lakes in Hungary, like most of the natural advantages of that rich country, are in a state of excessive neglect: the only ones that are put to any use are four that lie between Dobritzin and Groswaradin. These in the winter season, when full of water, are from one to two miles in circumference, but by the middle of April or the beginning of May they are generally dried up, except some pits that have been sunk by art below the general level. In a few days after the water has disappeared, the whole surface of the cavity becomes white with

saline efflorescences of natron mixed with a little sulphat of soda: these being removed, a fresh incrustation is formed in three or four days, and continues to be renewed with equal rapidity during the whole dry season of the year. A very heavy shower is sufficient to fill the lakes, but in a day or two they are dry again, so that no considerable interruption is experienced till the latter end of October; by this time the water in the pits is fully saturated with natron, a considerable proportion of which crystallizes during the first frosts of autumn, and thus finishes the harvest of the year, for after this the rains set in, and the lakes continue full of water till the ensuing spring. The soil is a stiff blue clay covered by a white calcareous sand, and is probably impregnated with salt as the *falsola* and other succulent saline vegetables flourish here in great abundance.^d The Hungarian as well as the Egyptian natron seems to be brought into commerce without undergoing any preparation, as it appears in pulverulent masses of a dirty grey colour. The Hungarian natron has been analysed by Lampadius, and the Egyptian by Klaproth,^e with the following results.

Egyptian natron		Hungarian natron	
32.6	—	14.2	Carbonat of Soda
20.8	—	9.2	Sulphat of Soda
15.	—	22.4	Muriat of Soda
31.6	—	45.	Water
—	—	9.2	Earthy residue
100.0	—	100.0	

By far the greater part however of the soda that is employed is of vegetable origin, and like potash, is procured from the combustion of plants. While the vegetables that grow in common soil yield potash, those which flourish in salt water, or on the sea shore, or wherever the ground is strongly impregnated with salt yield soda. Of vegetable soda there are two varieties, namely, *barilla* and *kelp*; the former being made from the plants of the genera *falsola*, *falicornia*, &c. that grow on the sea shore, the latter being the produce of *fuci* and other marine plants.

The best *barilla* is made from the *falsola* soda, which is an object of extensive and sedulous cultivation to the Spaniards, on the shore of the Mediterranean, especially in the vicinity of Alicante. It is sown in light low soils that are embanked on the side next the sea, and furnished with flood-gates, by which the salt water may be let in occasionally. In autumn when the

^c *Memoirs sur l'Egypte.*

^d *Jour. des Mines, No. 2. p. 117.*

^e *Analyt. Ess. ii. p. 60.*

feeds are ripe, the crop is cut down and dried; the feeds are rubbed out, and the rest of the plant is burnt in very simple furnaces, the temperature of which is just high enough to cause the ashes to enter into a state of semifusion, and concrete into compact cellular masses. The most esteemed variety of this salt is called *sweet barilla*; it is of a greyish blue colour, and is covered over with a saline efflorescence when exposed for a time to the air: it is exceedingly hard, and when applied to the tongue discovers a sharp pungent alkaline flavour.

We possess an interesting analysis of the *falsola soda* by Vauquelin:^f a remarkable quantity of azot enters into the composition of this vegetable, thus giving it a striking analogy to animal matter. 500 parts of the recent plant when carefully burnt afford oil and ammonia, and prussic acid, and leave behind 100 parts of ashes. 500 grains of the ashes when carefully lixiviated afford 113 grs. of muriated soda, and 159 grs. of crystallized (68 grs. of dry) carbonat of soda, the insoluble residue consists of 204 grs. carbonated magnesia, and 100 grs. of sand and oxyd of iron; to which are to be added 23 grs. of water not as a necessary but an accidental part, and therefore subject to considerable variation.

The Alicant barilla being composed of the same *falsola soda*, contaminated in some degree with weeds and other impurities that are unavoidable where a large quantity of materials is operated on, ought to bear a considerable resemblance in its analysis to that of *falsola soda* just mentioned. Mr. Kirwan^g has examined the component parts of sweet barilla, but unfortunately we are not able to trace the smallest similarity between the results of his analysis and that of Vauquelin: according to him a pound troy of barilla contains

1219	842	Dry caustic soda
	250	ditto impure
	127	ditto mixed with muriated soda
	125	Sulphat of soda
	70	Muriat of soda
	960	Carbonic acid
	542.86	Lime
	127	Magnesia
	131.23	Alumine
	249.58	Silex
	20	Unexamined earth
	861.32	Charcoal
	4306.49	
	1453.51	Water
	5760.00	

A minute examination however into the experiments upon which the above proportions are founded will discover some inconsistencies which forbid us to place an implicit reliance on them. These we shall mention, not with a view to depreciate the well earned reputation of Mr. K. but to show the necessity of a further examination into a subject so intimately connected with some of our most important manufactures. It appears from Mr. K's experiments that of the whole 5760 grs. of barilla, 2857 were soluble in water, the insoluble residue when reduced to the same apparent dryness as the original barilla, amounting to 2903 grs. or somewhat more than one half. Now 480 grs. (or one ounce) of the entire barilla when treated with muriatic acid lost 80 grs. of carbonic acid, therefore the whole quantity of carbonic acid in a pound of barilla $= 80 \times 12 = 960$ grs. But 480 grs. of the insoluble residue yielded by the same treatment 125.5 grs. of carbonic acid, and as the whole quantity of this amounted to something more than 6 ounces, the total amount of carbonic acid in the residue is $= 125.5 \times 6 = 753$ grs. Hence 960 grs. — 753 = 207 grs. indicate the quantity of carbonic acid contained in the soluble part of the barilla. But 207 grs. of carbonic acid indicate only 491.6 of dry, or 1293 grs. of crystallized, carbonat of soda, and it is not probable that the soda contained in the barilla was very caustic, since Mr. K. obtained crystals from the lixivium without, as appears, taking any measures for saturating the alkali further than performing the evaporations and coolings, to the number of 18 in the open air. Another objection arises from the amount of carbonic acid in the insoluble residue. The only ingredients in the residue capable of uniting with carbonic acid are the lime and magnesia, but 543 grs. lime require 444.2 carbonic acid and 127 grs. magnesia 95.9

540.1

The whole amount however of carbonic acid contained in the residue is = 753 grs. therefore (753 — 540.1 =) 212.9 grs. of carbonic acid remain, without any base with which they can combine.

It is also obvious that the amount of charcoal is excessively exaggerated. The insoluble residue containing the charcoal, was, after a long lixiviation with hot water, dried in a heat below redness, and was then supposed to have lost all its water, it was then calcined at a white heat,

^f An. de Chim. xviii. p. 76. ^g Examination of Alkalies used in bleaching.

and the whole loss of weight, deducting that of the carbonic acid thus expelled, was supposed to be the weight of the charcoal: but charcoal that had been soaked in hot water can by no means be dried at a temperature below a red heat, and therefore a large deduction must be made from the charcoal, on account of the water contained in it.

On referring to the results of the analysis we find 250 grs. set down as dry caustic soda, but somewhat impure: this is entirely founded on a gross blunder. Among the crystalline salt deposited by the lixivium was a portion of 346 grs.: this consisted of "a mixture of vegetable and mineral alkali, with a proportion of extractive matter and some digestive salt." The "mere alkali" contained in this is estimated by Mr. K. at 253 grs.: but this is impossible, for 250 grs. of mere soda would produce 1136 grs. of carbonated soda, whereas the salt in question with all its impurities, amounted only to 346 grs. A similar objection may be made to the 127 grs. set down as dry caustic soda mixed with muriated soda. Mr. K. says, "I obtained 127 grs. of a mixture of mineral alkali and common salt;" but this like the former was procured by crystallization, and therefore the 127 grs. even if they were pure carbonated soda would indicate no more than 28 grs. of pure soda.

Kelp is made of what is vulgarly called seaweed or sea wrack (whence the French term *soude de vareck*) that is of such of the leafy fuci, principally the *vesiculosus* and *ferratus*, as grow on rocks in the sea between the high and the low-water mark. The most favourable situation for these plants is a sheltered bay full of calcareous rocks: for limestone is not only more favourable to the growth of these fuci than any other kind of stone, but from its lying generally in nearly horizontal beds is more accessible at low-water than those rocks which affect a more vertical inclination, and therefore form narrow ridges. The season for gathering the plants is from May to August. On the British coasts they are cut with a scythe as close to the rock as possible, and then bound up into large bundles, which being fastened to one end of a long rope, the other extremity of it is tied to a boat, and thus the labour of two or three men is capable of towing several tons weight to the shore. The practice of cutting the stems is however by no means so judicious as the French method of tearing them up by the roots with instruments like rakes; for it has been clearly shown^a that

the stems when once cut never throw out any more leaves, and the root being a long time in decaying, occupies unprofitably the space which otherwise would be filled by young plants. The large bundles when landed are to be opened and their contents spread thinly on the shore to dry, turning them from time to time, lest they should ferment, by which both the quantity and quality of the kelp would be greatly deteriorated. The ware when dry should be stacked secure from rain for a few weeks till it becomes covered with a white saline efflorescence, and then it is ready to be burnt. The furnace employed for this purpose used to be, and in many parts still is, nothing but a round pit three or four feet deep, and seven or eight feet across, lined with stones: the more skilful kelp-burners however make use of a kiln of the following construction.ⁱ It is built of stone in the shape of a long open coffer, being 28 inches wide in the clear, about 2½ feet high, and from 8 to 18 feet long. The bottom of the kiln being covered with brush-wood or heath, a thin stratum of the dried ware is shaken lightly upon it, and fire is applied to the leeward end of the kiln. It must now be gradually supplied with fresh ware thrown lightly on wherever the combustion reaches the surface: if the weather is perfectly calm no further precautions are required than to take care that the fire is not stifled, but if it blows ever so little the windward side of the kiln must be covered with sods, and even both sides if the weather is at all boisterous. When all the ware has been thrown on that is intended to be used at one time, care must still be taken to cover every spot where the fire reaches the surface with a little of the charred, or least burnt part, laid lightly on by means of a fork. After a time that part of the mass which is nearest to the sides is seen to soften or melt, and now begins the most critical part of the whole process. An iron bar previously heated is to be introduced among the soft matter, which by this means is to be slowly stirred up and incorporated, adding by degrees some of the less burnt portions, and in this manner the whole is to be kneaded together till it becomes a pasty semi-fluid mass. It is a matter of considerable dexterity so to perform this process as to be able to mix the dust and fragments of a preceding burning with the present, without too much cooling the whole. If when this incorporation of the materials is begun the mass is too hard and dry, by waiting a short time it will be found to have acquired the necessary temper, but if it

^a Mém. des Sciences, 1772. Part ii. p. 70.

ⁱ Repertory xii. p. 246.

is dry and pulverulent like ashes, it is expedient to have recourse to a little common salt, which acting as a flux will begin the fusion; or if the heat is very languid some pulverized brimstone may be made use of. When the kelp has been thus prepared and is grown cold, it is broken into large lumps and is fit for sale. Well made kelp is of a bluish grey colour, sometimes approaching to green; it is of a more or less cellular texture, and contains pieces of charcoal enveloped in the mass: when breathed on it emits a faint sulphureous odour; to the taste it is caustic and alkaline, mixed with the flavour of common salt. It yields easily to the knife, but possesses a considerable degree of toughness. If dry it is usually covered with a white saline efflorescence. The proportion of pure soda which it contains varies, according to Kirwan and Jameson,^k from 1.25 to 5. *per cent.* For the analysis of barilla and kelp the same means are to be employed as have been detailed in the preceding article.

Another source of carbonated soda which we have not yet mentioned, is common salt: but the various methods of decomposing this so as to obtain the alkaline base, either pure or combined with carbonic acid, belong more properly to *MURIAT of Soda*, to which we refer the reader.

Pure carbonated soda from whatever substance, and by whatever means it is procured, is essentially the same. Its usual state is that of clear colourless crystals, in the form of rhomboidal octahedrons, or oblique tetrahedral prisms. To the taste it is sweetish, cooling, and subalkaline. It is soluble in $2\frac{1}{2}$ times its weight of water at 50°, and at a higher heat dissolves in its water of crystallization. By exposure to the air it effloresces, and is converted into a white mealy powder, with the loss of a great part of its water, and this powder when kept for some time at a very low red heat concretes into lumps, loses a small portion of its carbonic acid and all its water, and is then called *desiccated soda*: in preparing this from the crystallized carbonate, the salt should be merely laid thinly on a plate at some distance from the fire, till it is completely effloresced, otherwise by too sudden a heat it will dissolve in its own water, and then is very troublesome to manage. The component parts of crystallized carbonate of soda have been variously estimated, though the difference has not been very great: we shall mention the proportions as given by Bergman, and those adhered to by Mr. Kirwan.^l

^k Mineralogy of Shetland, p. 193.

Bergman		Kirw.
22	—	21.58 soda
16	—	14.42 carbonic acid
62	—	64. water of crystalliz ^a
—	—	—
100.	—	100.00

Soda, however, is capable of combining with a larger proportion of carbonic acid, by dissolving the crystallized carbonate in water, and then throwing in carbonic acid gas: the crystals that are now deposited will be found to contain a considerably less quantity of water, and their sweetish subalkaline flavour will be exchanged for a cooling saline one; so that in this state it resembles the trona. It has not, however, been analyzed with such accuracy as to enable us to state the proportions of its ingredients.

Carbonated soda is decomposed with abstraction of its base, by almost all the other acids, and with abstraction of its acid by barytes, lime, strontian, and potash.

The purposes to which carbonated soda is applied are in general the same as those for which carbonate of potash is used: the circumstances that induce the occasional preference of one to the other, will be mentioned in their proper places, especially in GLASS making, SOAP making, and DYING.

CARBONAT OF BARYTES.

Under the term *WITHERITE* the mineralogical description of the native carbonated barytes will be described, and the methods of analysing this compound.

The several methods of procuring the *artificial* carbonate of barytes are described at length under the article *BARYTES*.

It will be sufficient to mention in this place that this carbonate appears by the analyses of Klaproth and Pelletier to be composed (when previously dried and ignited for a few minutes in a low red heat) of 22 parts of carbonic acid and 78 parts of barytes, perhaps with a trifling portion of water.

The artificial carbonate is much more readily soluble in acids than the native. The muriatic or the nitric, considerably diluted, dissolve it with ease, and a copious effervescence.

Barytes has so strong an affinity for the carbonic acid that barytic water becomes covered with a pellicle of regenerated carbonate instantly on exposure to air, and breathing through it renders it turbid and milky almost immediately. The same effect takes place with lime-water, but with less rapidity.

^l On Mineral Waters, Table iv.

This carbonat is scarcely in any degree soluble in water, but when in very fine powder and diffused through water, if a stream of carbonic acid is sent through, the water then dissolves, according to Fourcroy, about $\frac{1}{850}$ of its weight. The carbonat is not crystalizable from this solution. By exposure to the air the excess of carbonic acid flies off, and the carbonat of barytes is again precipitated.

CARBONAT OF STRONTIAN.

As in the former article, the methods of procuring this substance artificially from the sulphat of strontian are described under the earth itself. (See STRONTIAN.) The analysis and properties of the native carbonat of strontian belong to the article STRONTIANITE.

Carbonat of strontian dried and gently ignited is composed, according to Klaproth, of about 30 parts of carbonic acid with 70 of strontian. Nearly the same observations apply to this carbonat, as mentioned in the former article, but the affinity for carbonic acid is not so strong, and it dissolves somewhat more easily.

CARBONAT OF LIME.

Under the article LIMESTONE most of the very important natural varieties of this carbonat, with the mode of analyzing, will be described: and under LIME, the method of freeing these earthy substances from their carbonic acid.

Carbonat of lime is readily prepared artificially by adding a carbonated alkali to the muriat, nitrat, or any other calcareous salt. Carbonated ammonia is best to obtain it in perfect purity, as all the last portions of adhering alkali are totally expelled by drying. When pure, and quite dry, after gentle ignition in a heat barely red for about ten minutes, this carbonat consists simply of 45 per cent. of carbonic acid and 55 of lime, which numbers may be conveniently assumed in all analyses. None of the carbonic acid properly belonging to the earthy carbonat is expelled in a heat below thorough redness.

Carbonat of lime is scarcely in any sensible degree soluble in pure water, but with an excess of carbonic acid it dissolves in water without difficulty. Thus if carbonated water (or water holding carbonic acid in solution) be added in small quantity to lime-water, an instant milkiness ensues, and a precipitate of carbonat of lime; but if an excess of carbonated water be added, the mixture again becomes clear by a solution of the carbonat of lime in the excess of carbonic acid. By far the greater number of natural waters coming immediately from the

earth, such as pump—well—mineral waters, hold in solution some carbonat of lime, and hence they become turbid by boiling, the heat expelling the excess of carbonic acid that held the earthy carbonat in solution.

These solutions of any of the carbonated earths in carbonic acid, give apparently opposite indications by the coloured tests. Paper stained red with Brazil wood is turned blue by all the alkalies, and also by the carbonated earths. Hence in the above solution this change of colour takes place on account of the carbonated earth. On the other hand the purple of litmus is changed to red by acids, and on account of the excess of carbonic acid this solution also reddens litmus-paper. ^a

From the experiments of many accurate analysts compared by Mr. Kirwan, ^b it appears that the quantity of carbonic acid necessary to hold carbonat of lime in solution, is inversely in proportion to the water with which it is mixed, as indeed might be expected, since pure water must have some, though a hardly appreciable action on carbonat of lime independent of any excess of carbonic acid. Where the proportion of water to carbonated lime is very great, as for example, about 12000 to 1., the weight of the excess of carbonic acid necessary for solution is only about half that of the carbonat; and in all cases, however small the quantity of water, carbonated lime is soluble therein with the half of its own weight of carbonic acid.

CARBONAT OF MAGNESIA.

This earthy salt is not found native, except largely admixed with carbonat of lime in several of the limestones, and in solution in many natural waters.

The artificial carbonated magnesia (the common magnesia, or *magnesia alba* of the shops,) is prepared by decomposing the sulphat of magnesia or Epsom salt with common carbonat of potash. To succeed perfectly in this preparation several precautions are requisite. The following is the process usually given. Take a pound of sulphat of magnesia dissolved in about five pints of water, add this to a pound of good purified pearl ash, or prepared carbonated potash, dissolved in a like quantity of water, and boil them for some minutes. A copious white precipitate is produced on the moment of mixture, which renders the whole mass extremely thick. Strain it while hot through linen (not paper) and wash the precipitate left on the strainer by repeated affusions of a very large quantity of boiling water, till it comes away tasteless. The pre-

^a Bergman.

^b On Mineral Waters.

precipitate gently dried becomes a perfectly white extremely light tasteless powder, which is common magnesia.

A double decomposition takes place in this process, the sulphuric acid quitting the sulphat of magnesia to unite with the potash, and the magnesia uniting with the carbonic acid of the alkali employed. The sulphat of potash being a salt of very sparing solubility in water, renders it necessary to wash the precipitate so abundantly. The drying of the carbonat of magnesia is tedious, for being excessively light and spongy, it retains a large portion of water, which cannot be separated by filtration. In the manufacture in the large way, the paste of magnesia and water is spread on slabs of chalk, which absorbs the water eagerly and much hastens the drying.

Common carbonat of magnesia consists of carbonic acid, water and magnesia in somewhat varying proportions. By being calcined for some time in a red heat, both the water and carbonic acid are expelled, and the entire loss by calcination is on an average about 55 per cent. On the other hand, this carbonat when added to an acid, effervesces violently, but only parts with its carbonic acid in the effervescence, and this loss is about 34 per cent, consequently the constituent parts of 100 parts of the common carbonat of magnesia will be, when dried in a gentle heat,

Magnesia	-	-	-	-	45
Carbonic acid	-	-	-	-	34
Water	-	-	-	-	21
					100

The quantity of alkali commonly used in obtaining magnesia is more than is necessary to decompose the magnesian sulphat, and probably one-fourth or one-fifth less would be sufficient.

Common magnesia is scarcely at all soluble in pure water, but with an additional quantity of carbonic acid its solubility increases largely. Hence in making common magnesia it is advisable to boil the ingredients on mixture, by which a considerable quantity of loosely combined carbonic acid is expelled, which otherwise would unite with part of the magnesia, render it soluble in water, and it would be carried away in the washings. Hence the more the alkali employed is saturated with carbonic acid (beyond the exact dose necessary for the precipitated magnesia) the less will be the product left on the filter, unless the boiling be continued a longer time.

This leads to the other distinct species of solid carbonat of magnesia, namely the *crystallized*, or that which is saturated with carbonic acid. It may be prepared in several methods. If carbonated alkali be mixed with sulphat of magnesia, *without heat*, and the mixture left to spontaneous evaporation, small long four-sided prismatic crystals of carbonated magnesia will be deposited. A neater and better way of procuring them is the following. Pass a stream of carbonic acid for some time through water, in which common carbonated magnesia is suspended. The agitation occasioned by the bubbles of gas will prevent the magnesia from entirely subsiding, and it will absorb much of the carbonic acid and dissolve in the water. Decant the clear liquor, and suffer it to evaporate in a heat not exceeding that of a warm room. After a while the carbonated magnesia will separate in crystals. This crystallized salt is composed of about

Magnesia	-	-	-	-	25
Carbonic acid	-	-	-	-	50
Water	-	-	-	-	25
					100

It is soluble in 48 times its weight of cold water, and in much less when the water also has an excess of carbonic acid.

Carbonated magnesia in any state is decomposed readily and completely by potash, soda, lime, barytes and strontian; the carbonic acid uniting with these substances and leaving the magnesia pure. It is also decomposed by all the salts with the basis of barytes, strontian, and lime. Hence a common caution in preparing magnesia, to wash the precipitate with water as pure as possible and free from calcareous salts; for as most spring-waters contain some sulphat of lime, this salt is decomposed by the carbonat of magnesia, and carbonat of lime is formed, which mixes with the magnesia. This is of little importance medicinally when the magnesia is used in its common state, but after calcination the earth contains a small portion of quick-lime, the effect of which might be felt in large doses.

Ammonia and magnesia appear to have very nearly equal affinities for carbonic acid, and hence it is that either of the two will only partially decompose the saturated carbonat of the other. Thus if ammonia is added to crystallized carbonat of magnesia in solution, the precipitate is not pure magnesia (which it would be with the other alkalies) but the sub-carbonat, or common magnesia alba, and vice versa if pure mag-

magnesia be added to the carbonated ammonia, the sub-carbonat of magnesia is equally produced. In either case also a part of the ammonia unites with the magnesia, according to Fourcroy, forming a triple salt, the *ammoniaco-magnesian carbonat*. The same triple salt also is formed by adding the compound muriat of ammonia with magnesia to carbonat of potash or soda. The properties of this triple salt are not well established, but its supposed formation in the above circumstances corresponds sufficiently well with the known tendency of ammonia to such triple combinations.

Magnesia is only used in medicine.

CARBONAT of *Alumine, Glycine, Zircon, &c.* For the remaining earthy carbonats see the respective earths.

CARBONATS *Metallic.* See the respective metals.

CARBUNCLE. See SPINELL.

CARMINE is a beautiful red precipitate of the colouring matter of COCHINEAL (which see).

CARNELIAN. See CHALCEDONY.

CARTHAMUS. See SAFFLOWER.

CARTILAGE. This organ which appears to hold somewhat of an intermediate state between ligament and bone appears, according to Mr. Hatchett's researches to consist chiefly of condensed albumen.

Some parts, such as the joinings of the ribs, remain cartilaginous through life; in others the cartilage is the first rudiment of bone, that which determines its shape and position, and it becomes solid bone by the gradual deposition of osseous matter. These may be again separated in a great measure by acids which dissolve the bone and leave the cartilage. See BONE and ALBUMEN.

CASSIUS, *Powder of*, is a beautiful precipitate formed by immersing tin in a solution of gold, or by mixing the nitro-muriats of each metal. It is used to give the finest ruby colour to GLASS. See also GOLD.

CATECHU or TERRA JAPONICA.

This substance, concerning the origin of which there was formerly much doubt, is an inspissated extract prepared in several parts of India, from a species of Mimosa, by decoction of the wood and evaporation to dryness. The tree is called in the Bahar province *Coira*, and the extract has the several names of *catechu, cutch* or *cachou*.

It is thus prepared, according to Mr. Kerr, an eye-witness.^a After felling the trees the manufacturer cuts off all the exterior white part of the wood, which is rejected. The inner

wood which is red, and from which alone the extract is prepared, is cut into chips and boiled with water till half is evaporated. This strong decoction is then poured off without straining, into a shallow earthen pot and evaporated to one-third by fuel, after which the thorough drying is completed by the heat of the sun, the thickened extract being spread thin on a mat and exposed to the air. In this simple method is the catechu prepared, but it is often mixed accidentally or fraudulently with sand or other earthy impurities, sometimes to the amount of one-eighth of the whole, as appears on analysis.^b

There are two varieties of catechu brought to this country, from Bengal and from Bombay, but differing very slightly in chemical qualities.

Catechu is of a red brown colour, uniform in texture, brittle and friable, and without smell. Its specific gravity from 1.28 to 1.39. The taste is strongly astringent, and at first somewhat bitter, but afterwards leaves a permanent and agreeable sweetness. It dissolves slowly and totally in the mouth, the earthy impurities excepted.

Catechu is important in a chemical point of view, from the unusually large quantity of tannin which it has lately been found to contain, and which therefore promises to render it useful in the preparation of leather. See TANNIN.

By the analysis of Mr. Davy,^c at the suggestion of Sir J. Banks, it appears that there is very little difference between the two species, and therefore the description of one will serve for both.

Catechu is almost totally soluble in hot water. The solution is of a deep red-brown, and slightly reddens litmus. By long decoction a solution is made, which yields by evaporation as much as $\frac{1}{6}$ of its weight of solid matter.

With chemical reagents nearly the same effects were produced as when the same reagents are added to infusion of GALLS, and will be mentioned under that article. In particular the presence both of the gallic acid and of tannin were fully ascertained, the former among other tests by the black produced by sulphat of iron, and the latter by the copious precipitate with animal gelly.

Besides tannin and gallic acid, catechu contains a peculiar extract, and also a substance resembling mucilage. The latter is left nearly pure after the action of alcohol, which readily dissolves all the rest. It scarcely differs from common gum mucilage. The extractive matter

^a Medical Observations, Vol. 5.

^b Lewis's Mat. Med.

^c Phil. Trans. for 1803.

is soluble in water, but much less easily than the tannin, and hence if the catechu in fine powder be repeatedly and for a short time washed with water, all the tannin is dissolved (which is known by no longer precipitating the solution of glue) and also most of the mucilage, and the residue is a pale red extract, only slightly astringent, but considerably sweet when chewed. It dissolves both in water and alcohol, acquiring a deeper colour by exposure to air.

Catechu therefore consists chiefly of—1st. a very large portion of tannin, to which it owes its astringency, and the very great powers which it possesses as a material for tanning leather: 2d. of a peculiar extract, in which resides the sweetness of taste for which this extract is valued in the East: and 3d. a small portion of mucilage, inert and insipid. Mr. Davy found that 200 grains of the Bombay catechu contained 109 grains of tannin, 68 of extract, and 13 of mucilage, with 10 of earthy residue. The same quantity of the Bengal catechu gave of the same ingredients 97 grains, 73, 16, and 14.

Catechu is used in the East, as it is said, for many processes of dyeing, and would doubtless answer in many cases where galls are now used. But its chief consumption is as an ingredient in the betel composition, which is so universally chewed. It is used in this country only in medicine, as a very valuable astringent, but its tanning powers deserve farther trial.

CAT'S-EYE. See KATZEN-AUGEN.

CAUSTICITY. *Aetzbarkeit*, Germ.

A substance is usually said to be caustic when it produces the same effect to the tongue as that of actual fire, that is, an immediate sensation of burning, followed with a slight disorganization of the surface actually in contact. Thus the alkalies are called *caustic* when deprived of carbonic acid, because, when at all concentrated, they then burn and blister the tongue almost instantly.

Caustic substances are also generally *corrosive*, or such as act upon organized matter and decompose it with great rapidity.

The term caustic prefixed to the alkalies and earths to distinguish the pure or de-carbonated state, is omitted in the modern nomenclature; being rendered unnecessary by the use of the term *carbonat*; thus to the terms *caustic potash* and *mild potash* are substituted those of *potash* and *carbonat of potash* respectively. Some confusion still arises occasionally from this change; the term *soda* for example, meaning in chemical language *pure or caustic soda*, and in commerce and common use meaning the *mild, carbonat of*

soda. In this work where the carbonat is meant, it is always so expressed.

CAUSTIC *Lunar* is the nitrat of SILVER melted and cast into cylindrical pieces about the size of common slate-pencils, for the use of surgeons.

CEMENTATION. *Cementiren*, Germ.

This term is applied to a process in the dry way similar to digestion in the moist, and means the exposure of any substance to a regular furnace-heat in a crucible, stratified, or otherwise covered, with some kind of powder, which is intended to produce a chemical change. Thus iron bars are converted into steel by being cemented with a powder of bone-ash and other materials: copper into brass by cementation with a powder of calamine and charcoal, and the like. The powder is in this case called *Cement-powder*.

CEMENT-COPPER. The copper procured from the sulphat by precipitation with iron is so called. See COPPER.

CEMENTS and LUTES. Under this article may be mentioned the receipts for preparing some of the most useful substances of this kind that are required in common chemical operations.

The uses of lutes and cements are, either to close the joinings of chemical vessels to prevent the escape of vapours and gases during the processes of distillation, sublimation and the like: or to protect vessels from the action of the fire which might crack, or fuse, or calcine them: or sometimes to repair flaws and cracks, and for a variety of other smaller purposes.

The subject of *calcareous cements*, such as mortar, tarras, and other substances used to close the joinings of bricks or stones in buildings, will be mentioned in the following article.

When a lute is applied over the whole surface of a vessel (as to a glass retort when it is intended to be heated red-hot) the process is termed *lorication* or *coating*. Iron furnaces are also *lined* or *coated* on the inside with earth to prevent the iron from being destroyed by the constant action of the fire.

From the vast variety of receipts for lutes and cements of different kinds the following may be selected, which will answer most of the purposes of the experimental chemist.

To prevent the escape of the vapors of water, spirit, and liquors not corrosive, the simple application of slips of moistened bladder will answer very well for glass, and paper with good paste for metal. Bladder to be very adhesive should be soaked some time in water, moderately warm, till it feels clammy, it then sticks very

well. If smeared with white of egg instead of water, it adheres still closer.

Another very convenient lute is linseed meal moistened with water to a proper consistence, well beaten, and applied pretty thick over the joinings of the vessels. This immediately renders them tight, and the lute in some hours dries to a hard mass. Almond paste will answer the same purpose.

The use of the above lute is so extensive that no other is required in closing glass vessels in preparing all common distilled liquors, and it will even keep in ammonia and acid gasses for a longer time than is required for most experimental purposes. It begins to scorch and spoil at a heat much above boiling, and therefore will not do as a *fire lute*. It is still firmer and dries sooner when made up with milk, or lime-water, or weak glue.

A number of very cohesive cements impervious to water, and most liquids, and vapors, and extremely hard when once solidified, are made by the union of quick-lime with many of the vegetable or animal mucilaginous liquors. The variety of these is endless. We may first mention the following as it has been extensively employed by chemists for centuries. Take some whites of eggs with as much water, beat them well together, and sprinkle in sufficient slacked lime to make up the whole to the consistence of thin paste. The lime should be slacked by being once dipped in water, and then suffered to fall into powder, which it will do speedily with great emission of heat, if well burnt. This cement should be spread on slips of cloth and applied immediately, as it hardens or *sets* very speedily. While hardening, it may be of use to sprinkle over it some of the lime in fine powder. This cement is often more simply, and as conveniently managed by smearing slips of linen on both sides with white of egg, and, when applied to the joining of the vessel, shaking some powdered lime over it. It then dries very speedily.

Another lute of the same kind, and equally good, is made by using a strong solution of glue to the lime, instead of the white of egg. It sets equally soon, and becomes very hard. A mixture of liquid glue, white of egg, and lime, makes the *lut d'ane*, which is so firm that broken vessels united with it are almost as strong as when sound. None of these lutes however will enable these vessels to hold liquids for any great length of time. Milk or starch with lime make a good but less firm lute.

A very firm and singular lute of this kind is

made by rubbing down some of the poorest skimmed-milk cheese with water to the consistence of thick soup, and then adding lime and applying as above. It answers extremely well. Lime and blood with a small quantity of brick-dust or broken pottery stirred in is used in some places as a very good water-cement for cellars and places liable to damp.

Paris plaster mixed with egg, milk, glue, starch, or any mucilaginous liquor, also makes a good lute.

Some artists mix other earths with the above materials. Thus a very good cement is made with equal parts of clay and lime, about $\frac{1}{3}$ of flour and white of egg; or as is used by many of the aqua-fortis makers, a mixture of colcothar, lime, and white of egg.

All the above-mentioned cements with lime become very hard by drying, insomuch that they cannot be separated from glass vessels without the help of a sharp knife and some violence, and hence delicate vessels and long thin tubes cemented with it are apt to break when the apparatus is taken down, and sometimes even by the mere force of contraction in setting. It is a great advantage however that they may be applied immediately to any accidental crack or failure of the lute already on, notwithstanding a stream of vapour is bursting through, and in large distillations it is of advantage always to have some of the materials at hand.

These lutes will not confine very corrosive acid vapours perfectly for a great length of time, but will answer for other purposes, particularly where a complicated apparatus is to be kept steadily united and air-tight. They will bear nearly red-heat without material alteration.

Another kind of lute which is the most perfect for confining acid vapours for any length of time, and which never hardens to an inconvenient degree is the *fat lute* as it is called. This is made by taking any quantity of good clay, tobacco-pipe clay for example, thoroughly dry, but not burnt, powdering it in an iron mortar, mixing it gradually with *drying* linseed oil, and beating them for a long time to the consistence of thick paste. Much manual labour is required, and it should be continued till the mass no longer adheres to the pestle. Then make the edges of the glass or other vessels where it is to be used perfectly dry, and apply the lute carefully, and it will stand the longest process without failing. This grows firm enough to retain its place and to hold the vessels together, but may readily be separated by a knife. This lute much improves in adhesive-

ness by long keeping, which should be in a covered pan in a cool cellar. When wanted, it regains sufficient ductility merely by being beaten for a minute or two, or by the help of a few drops more of the oil. Good glaziers putty, which is made of chalk beat up with drying linseed oil, much resembles the fat lute in quality.

Another species of lute is that which is commonly applied round glass retorts when distillation with a full red heat is wanted to protect them from the sudden action of the fire, and to give them firmness, and enable them to bear this heat without flattening or falling together when red-hot, or melting with the fuel. A glass vessel so prepared with a thick earthen coating may be considered as an earthen vessel glazed on the inside. The substance used is a mixture of sand with just sufficient clay to make it adhere together, beat up with some kind of fibrous matter so as mechanically to increase the tenacity. A natural earthy mixture of the kind is Windsor loam, or an equally good one may be formed with coarse sand and clay or better with fragments of pottery coarsely ground (the fine part being separated by sifting and rejected) mixed with more or less clay according to the quality, so that it will just mould together when wet. For the fibrous matter, some use horse-dung, which appears the best, others, chopped straw or chaff, others, chopped horse and cow hair or tow, all of which answer the same purpose. A small quantity of these will suffice. Beaumé recommends about an ounce of cow's hair to five pounds of the earthy mixture. A good deal of water should be added when the materials are mixed, and much manual labour is required to diffuse the hair equally through the mixture. To apply it to a glass vessel, a retort, for example, take a sufficient quantity of the lute, spread it out flat on a table, lay the bottom of the retort on the middle of the mass, and then turn up the edges of the flat cake, and bring it over the rest of the glass, pressing it down with the fingers till it applies uniformly and closely. By this method the lute is without seam, and is much more likely to dry in the fire without cracking. Or else, bring the lute with sufficient water to the consistence of thick soup, dip the retort in, and it will come out thinly coated. Turn it round before the fire, and when dry dip it again in the lute to give a second coating, and so on to the required thickness, which may be from $\frac{1}{4}$ to $\frac{1}{2}$ an inch. A lute similar to this is

used as a lining to iron furnaces to confine the fire and prevent the iron from consuming by the constant heat. This lute is just so fusible as to begin to agglutinate in a full red heat, and hence, if it remains sound till thus hot, it will form an impenetrable coating to the glass within, from which it cannot afterwards be detached. The covers of crucibles and other vessels intended to bear fire may be luted with this earthy mixture. It is rendered still less liable to crack on the first heating, if, when thoroughly dry, it is smeared with linseed oil.

Sometimes however a still more fusible compound is wanted, particularly where very volatile and penetrating substances are distilled from an earthen vessel. These vessels are necessarily porous to a certain degree, independent of any casual cracks, from which the larger earthen vessels are seldom entirely free. When phosphorus (for example) is prepared by strongly heating charcoal and phosphoric acid in one of these retorts, the vapour of the phosphorus penetrates through the pores when thoroughly red hot, and much of it is lost. Nor will the last-mentioned luting entirely prevent this, so that it is a great saving to cover the retort first with a thin coat of a fusible glazing, which will melt on the surface as soon as red-hot, and close every opening. This glazing may be made by a variety of fluxes added to the proper dose of clay and earth, and mixed into a thin paste, and applied to the retort with a brush. The following management is recommended by Mr. Willis,^a a practical chemist, in distillation with large earthen retorts. Dissolve one ounce of borax in half a pint of boiling water, and add as much slacked lime as will make it into a thin paste. Spread it over the retort with a brush, and when dry apply over the whole a lute of slacked lime and linseed oil beaten till it is perfectly plastic. This becomes dry in a day or two, and is then fit for use. Stone retorts may thus be used several times with safety (always renewing the oil and lime lute) whereas in the common way, and even with the clay and hair lute they generally crack when cooling, or on being heated a second time. If during the operation the retort should crack, Mr. W. advises to spread some of the oil composition thickly on the part, and sprinkle some slacked lime over the whole, which will prevent the further escape even of the penetrating vapour of phosphorus, and may be safely applied even when the retort is red-hot. When prepared somewhat thicker

^a Repertory, vol. i.

it is very proper as a general lute for a great variety of purposes, and will never harden so as to break the vessel.

Often a fire lute is required to join the covers to crucibles, or for similar purposes, so as to keep them air-tight when hot. A very valuable composition of the kind is made of glass of borax, brick-dust, and clay, finely powdered together and mixed with a little water when used. No very great nicety is required in the proportions, but about a tenth of borax is quite sufficient to bring the earths to that state of semi-vitrification which is desired. Litharge may also be used instead of borax, but the latter is by far the best, as it promotes that thin spreading fusion which is best calculated to be equally applied over an uneven surface, and besides, if a portion of the litharge-lute were to drop into the crucible it might possibly be reduced, and lead introduced into the results of the experiment.

A cement said to be useful to stop cracks of iron vessels intended to be strongly heated, is made of 6 parts of clay, 1 of iron filings, and linseed oil enough for mixture.

Another species of cement is what is termed by the French *Mastic chaud*, and consists of different kinds of oily and resinous substances, liquid when hot, and which become more or less solid by cooling. They are useful for a variety of miscellaneous purposes, for experiments with glasses over water or mercury, and others where only a very moderate warmth is used, and where it is of importance to keep out air and water. These will also confine acid vapors, but not the vapors of alcohol, turpentine, or essential oils, which dissolve most resinous substances. Most of them will stick very well to glass. Common sealing-wax is one of the most useful of these cements. A cheaper and less brittle cement is made simply by melting bees wax with about one-eighth of common turpentine. This may be made up into sticks to be used when wanted, being first melted or spread evenly with a hot iron. A greater portion of turpentine renders this lute softer, and more fusible, but somewhat pliable.

A very firm cement is made by 4 parts of rosin, 1 of bees wax, and when melted, 1 part of fine brick dust stirred in. This adheres with extreme firmness. Table knives are cemented to their handles by this mixture, and turners use a similar composition in some fine works to fix them to the lathe.

Chaptal found after many trials that the penetrating vapours of sulphureous acid in the

manufacture of alum were completely confined in a wooden chamber, lined very carefully with a mixture of equal parts of pitch, turpentine, and wax, boiled till all the essential oil was dissipated (which was known by the cessation of the bubbles) applied melted to the wood, and spread with a hot trowel over the joints. Vintners stop leaks in their casks with melted suet rubbed over, when cooling, with sifted wood-ashes, or previously mixed with the ashes in melting.

The use of gum arabic dissolved in water for cementing paper labels to bottles, and a great variety of miscellaneous purposes is known to every one. A still better cement for the same uses is isinglass dissolved in vinegar to a pretty thick consistence when warm. This congeals on cooling, and before it is used it should be gently warmed.

Many of the varnishes and oil paints are employed in rendering vessels air and water tight. Thus when canvas bags are fastened to a stop-cock tube for air-holders, the joining is made perfectly tight by tying over it slips of cloth or bladder soaked in spirit varnish.

The following cement is said to be very useful in joining together glass or steel. Take of mastich five or six bits as big as peas, dissolve in as much alcohol as will render them liquid. In another vessel dissolve as much isinglass (previously soaked in water) in brandy or rum as will make two ounces by measure of a strong glue; warm it and incorporate with it, by rubbing, two or three small bits of galbanum or ammoniacum, and then the mastich solution. Keep the cement in a bottle well stopped, and gently warm it before use.

Those fusible metallic compounds used to unite pieces of metal, form another totally distinct species of cements. These are termed **SOLDERS**, under which they will be described.

Some inconveniences occasionally attend the use of these lutes in chemical operations. The application of them takes up time and requires a little manual dexterity, which can only be learned by practice. In some nice experiments of research, where substances are decomposed by distillation, and all the products are to be analyzed, the lute itself is often slightly corroded or otherwise acted on, and introduces some confusion in the result. It is partly on this account, and chiefly to save trouble to the chemist, that the practice of closely fitting glass vessels by grinding is so much more used at present than formerly; but this is always expensive,

and in complicated apparatus much endangers the vessels by the partial stress on the parts that closely fit.

It may be added, that the modern use of Woulfe's apparatus, or similar contrivances, so completely takes away the pressure of expansive vapours in all distillations, that in many instances very simple lutes will answer now, where formerly it was necessary to render the joinings of vessels as firm as the vessels themselves. But the proper application of all these kinds of cements is of great importance to the practical chemist to prevent continual losses and disappointments.

CEMENTS CALCAREOUS.

In this article it is proposed to give an account of the various cements used in building, into which lime enters as an essential constituent part, and in order to treat the subject with a degree of clearness in some measure corresponding to its importance, it will be advisable to arrange every kind of calcareous cement under one or other of the following three divisions, first, simple calcareous cement: secondly, water cements: thirdly, mastichs or maltha.

§ 1. Simple Calcareous Cements.

This section includes those kinds of mortar which are employed in buildings on land, and generally consist of lime, sand, and fresh water.

The various kinds of marble, chalk, and lime stone, as far as regards their use in cements, may be divided into two species; the first being pure, or nearly pure carbonat of lime, the second containing besides from $\frac{1}{10}$ to $\frac{1}{12}$ of clay and oxyd of iron. Previous to burning or calcination, there are no external characters by which the simple limestones can be distinguished from the argillo-ferruginous ones; but the former, whatever may have been their colour in the crude state, become when calcined, of a white colour, while the latter possess more or less of a light ochery tinge. The brown lime is by far the best for all kinds of cements, but the white varieties being more abundant, and allowing of a larger proportion of sand, are generally made use of. It was an opinion of the ancients, and is still commonly received among architects, that the hardest lime stone, *ceteris paribus*, furnishes the best lime; hence marble was considered as superior to common limestone, and this latter to chalk. The experiments of Mr. Smeaton,^a however, show that this is entirely a mistake, common chalk and the hardest Plymouth marble, when similarly treated, affording cements of equal firmness.

When carbonated lime has been thoroughly burnt it is deprived of its water, and of all, or nearly all of its carbonic acid; if in this state it is plunged into water, and immediately taken out again, the water which it has absorbed will occasion the mass to crack and become excessively hot, and at length to fall into an impalpable powder, much of the water being carried off in the form of steam during the process. When lime has been thus slacked, if it is beaten up with a little water into a very stiff paste and allowed to dry, it will be found that the white limes, whether from chalk or marble, never acquire any degree of hardness, that the brown limes become considerably indurated, though not so much so as when mixed with sand, and that shell lime (procured by calcining sea-shells) concretes into a firm hard cement well qualified for dry building, although it falls to pieces in water.^b

A proper selection of sand is of great importance in the composition of mortar; the sharper and coarser it is, the better, both because it requires a smaller proportion of lime, which is the most costly ingredient, and because the mortar thus prepared is stronger than when fine grained and round sand is made use of. Sea sand requires to be well washed in fresh water to dissolve out the salt with which it is mixed, otherwise the cement, into which it enters, never becomes thoroughly dry and hard. The Roman builders were accustomed to allow four parts of coarse sharp pit sand, and only three parts of river or sea sand to one of lime.^c If, however, the cement was required to be very compact, the proportion of lime was increased: thus the mortar used in constructing reservoirs for water, consisted of two parts of the strongest lime and five parts of pure and sharp sand.^d

The weakness of modern mortar compared to the ancient is a common subject of regret, and many ingenious men taking for granted that the process used by the Roman architects in preparing their mortar is one of those arts which are now lost, have employed themselves in making experiments to recover it instead of attending to the directions left us in Pliny and other authors, which when illustrated by the actual practice of builders in various parts of Europe, seem to leave little or no doubt on the subject.

The characteristic of all modern artists, builders among the rest, seems to be to spare their time and labour as much as possible, and to increase the quantity of the articles they produce

^a Hist. of Eddystone Light House.

^b Ibid.

^c Pliny, Hist. Nat. Lib. xxxvi.

^d Ibid.

without much regard to their goodness; and perhaps there is no manufacture in which this is so remarkably exemplified as the preparation of common mortar, especially in London and its neighbourhood.

One radical fault is the use of chalk instead of stone lime, for although chalk when perfectly burnt is equally good as the hardest lime, yet it possesses two capital disadvantages, first, it will fall into a coarse powder on the application of water, when it is only partially calcined, which stone lime will not; and secondly, the cores or unburnt lumps may be broken down by a blow with the spade, and are therefore very seldom rejected as they ought to be. The whitest chalk is the worst of all, both as being the softest, and as being a *fat* lime, that is, containing no clay and iron, in consequence of which a larger proportion of sand may be incorporated with it, and the mortar becomes less compact. The yellowish grey chalk on the other hand is the best, since it is somewhat harder than the former, and being a *meagre* lime, containing a portion of clay, it will not admit of so much sand. The Dorking lime which is the best of those used in London, is a chalk lime of this description, and contains about $\frac{1}{17}$ of clay.*

Another essential fault in London mortar is the bad quality of the sand with which it is composed. This is pit-sand, but very different from the kind recommended by Pliny and Vitruvius; instead of being clean, large-grained, and sharp, it is of a dirty brownish grey colour, being soiled by a mixture of clay, and is composed of small round grains. Its fineness and smoothness cannot be amended, but by washing it well in running water the clay might unquestionably be got rid of, and this would be no trifling improvement; for Smeaton has shown by direct experiment that mortar of the best quality when mixed with a small proportion of *unburnt* clay never acquires that hardness and dryness which without this addition it would speedily have attained.

The method of preparing common mortar is also extremely imperfect. The lime being slacked by the addition of water, and the unburnt lime being broken down and mixed with the rest, a large quantity of dirty sand is added, and the whole being incorporated by means of a spade is reckoned to be fit for use; thus the principal point in the making of mortar, namely, beating the ingredients together so as to mix them thoroughly, is flurred over in a hasty careless man-

ner, and the result, as might be expected, is a crumbling mass scarcely fit for use. The Roman builders, on the other hand, after they had mixed together the materials, employing for this purpose a smaller proportion of water than is customary at present, put the mass into a large wooden mortar, and beat it till it ceased to adhere to the heavy wooden or iron pestle which was used on the occasion. A practice this which has been long followed by the Dutch with complete success, as will be shown in the next section, and the high utility of which is also proved by Mr. Smeaton, in his history of Eddystone light-house.

Fresh made mortar, if kept under ground in considerable masses, may be preserved for many months without injury; and the older it is before it is used the better, the builder taking the precaution to beat it up afresh previous to using it; for it not only sets sooner, but acquires a greater degree of hardness, and is less apt to crack. Pliny informs us that the ancient Roman laws prohibited builders from using mortar that was less than three years old, and to this circumstance he expressly attributes the remarkable firmness of the oldest buildings in the city. A similar law prevailed, and, we believe, still prevails in Vienna, requiring the mortar to be a year old before it is employed. But there is nothing which shows in so striking a point of view the advantage and necessity of beating mortar, and that the effect produced is owing to something more than a mere mechanical mixture of the ingredients, as the preparation of *grout* or liquid mortar. This differs from common mortar only in containing a larger quantity of water, so as to be sufficiently fluid to penetrate the narrow irregular cracks and interstices of rough stone walls, and is generally made by diluting common mortar with water either cold or hot. It not unfrequently happens that this grout refuses to set, and at all times it is a long while in acquiring the proper hardness: but if instead of common mortar, that which has been long and thoroughly beaten is employed, the grout will set in the space of a day, and soon after acquire a degree of hardness much superior to what is made in the common manner.

§ 2. *Water Cements.*

Although a well made mortar composed merely of sand and lime, if allowed to dry, becomes impervious to water, so as to serve for the lining of reservoirs and aqueducts, yet if the circumstances of the building are such as to render it impracticable to keep out the water

* Smeaton.

whether fresh or salt a sufficient length of time, the use of common mortar must be abandoned; for lime and sand if mixed together in any proportions, and put while soft into water, will in a short time fall to pieces.

Among the nations of antiquity the Romans appear to have been the only people who practised building in water, and especially in the sea, to any great extent. The bay of Baiæ, like our fashionable watering places, was the summer resort of all the wealthy in Rome, who not content with erecting their villas as near the shore as possible, were accustomed to construct moles, and form small islands in the more sheltered parts of the bay, on which, for the sake of the grateful coolness, they built their summer houses and pavilions. They were enabled to build thus securely in the water by the fortunate discovery at the neighbouring town of Puteoli of an earthy substance, which, from this circumstance, was called *pulvis Puteolanus* (powder of Puteoli). Puteolan powder, or as it is now denominated Puzzolana, is a light, porous, friable mineral of a red colour, and is generally supposed to derive its origin from concretion volcanic ashes thrown out from Vesuvius, near to which mountain the town of Puteoli is situated: it seems to consist of a ferruginous clay baked and calcined by the force of volcanic fire, and when mixed with common mortar, not only enables it to acquire a remarkable hardness in the air, but to become as firm as stone even under water. The only preparation which Puzzolana undergoes is that of pounding and sifting, by which it is reduced to a coarse powder: in this state, being thoroughly beaten up with lime, either with or without sand, it forms a mass of remarkable tenacity which speedily sets under water, and becomes at least as strong as good freestone. In the composition of water cements it is that the superior efficacy of argillo-ferruginous lime compared with the purer kinds is most strikingly manifest, and as building in water is generally very expensive and difficult to repair, every precaution should be taken to secure the goodness of the cement. In situations exposed to the violent shocks of the sea the difference of expence between the best and inferior kinds of mortar is so little, compared to the whole cost and the satisfaction of perfect security that the cement ought to be of the very best quality. That which was used by Mr. Smeaton, in the construction of Eddystone light house, was composed of equal parts by measure of flacked Aberthaw lime and Puzzo-

lana; but for works that are less exposed, such as locks and basins for canals, &c. the proportions of Puzzolana may be considerably diminished. A composition of this kind which has been found very effectual is 2 bushels of flacked Aberthaw lime, 1 bushel of Puzzolana, and 3 of clean sand; the whole being beaten well together with the proper quantity of water will yield 4.67 cubic feet of cement.

The Dutch have practised building in water to a greater extent than any other nation of modern Europe, and to them is due the discovery of a cement admirably well qualified for this purpose, and called tarras or trass. This is nothing more than wakke or cellular basalt, and is procured chiefly from Bockenheim, Frankfort on the Maine, and Andernach, whence it is transported down the Rhine in large quantities to Holland.^f It undergoes no further preparation than grinding and sifting, and being thus reduced to the consistence of coarse sand it is beaten up with the blue argillaceous lime from the banks of the Schelde, and thus composes the celebrated tarras mortar with which the mounds and other constructions for the purpose of protecting the lowlands of Holland against the sea are cemented. The strongest tarras mortar is composed of 2 measures of flacked lime, and 1 of tarras; another kind almost equally good and considerably cheaper, is made of two measures of flacked lime, one of tarras, and 3 of coarse clean sand; it requires to be beaten a longer time than the foregoing, and produces $3\frac{1}{2}$ measures of excellent mortar. When the building is constructed of rough irregular stones where cavities and large joints are to be filled up with cement, the pebble mortar may be most advantageously applied: this was a favourite mode of construction among the Romans, and has been used ever since their time in those works in which a large quantity of mortar is required. Pebble mortar will be found of sufficient compactness if composed of 2 measures of flacked argillaceous lime, half a measure of tarras or puzzolana, 1 measure of coarse sand, 1 of fine sand, and 4 of small pebbles screened and washed. Although the cellular basalt is the only kind admitted into the preparation of Dutch tarras, yet it appears from some good experiments of Morveau, on the subject, that the common compact basalt if previously calcined will answer nearly the same purpose.^g Great Britain is at a considerable annual expence in purchasing tarras from Holland, it may be worth while therefore to point

^f Vogel in N. Comm. Gott. iii. p. 51.

^g An. de Chim. xxxvii. p. 253.

out some of our domestic treasures of the same material. The compact basalt abounds in all the districts where coal is raised, and may therefore be procured easily, and calcined with the refuse coal so as to be sold at a cheap rate: the Calton hill adjoining to Edinburgh consists almost entirely of cellular basalt, and being but a short distance from the port of Leith, offers an inexhaustible abundance at small cost.

In some parts of the Low Countries coal ashes are substituted for tarras with very good effect, of which the valuable *cendrée de Tournay* is a striking instance. The deep blue argillous lime stone of the Schelde is burnt in kilns with a slaty kind of pit coal that is found in the neighbourhood: when the calcination of the lime is completed, the pieces are taken out, and a considerable quantity of dust and small fragments remain at the bottom of the kiln. This refuse consists of coal ash mixed with about $\frac{1}{4}$ of lime dust, from which the *cendrée* is thus prepared. About a bushel of the materials is put in any suitable vessel, and sprinkled with water just sufficient to slack the lime; another bushel is then treated in the same way, and so on till the vessel is filled: in this state it remains some weeks, and may be kept for a much longer time if covered with moist earth. A strong open trough, containing about two cubic feet, is filled about two-thirds full with the cement in the above state, and by means of a heavy iron pestle suspended at the end of an elastic pole is well beaten for about half an hour; at the end of this time it becomes of the consistence of soft mortar, and is then laid in the shade from three to six days according to the dryness of the air; when sufficiently dry, it is beaten again for half an hour as before, and the oftener it is beaten the better will be the cement; three or four times however are sufficient to reduce the cement to the consistence of an uniform smooth paste; after this period it is apt to become refractory on account of the evaporation of its water, as no more of this fluid is allowed to enter the composition than what was at first employed to slack the lime. The cement thus prepared is found to possess the singular advantage of uniting in a few minutes so firmly to brick or stone that still water may be immediately let in upon the work without any inconvenience; and by keeping it dry for 24 hours, it has afterwards nothing to fear from the most rapid current.

Somewhat analogous to the preceding is a cement used in certain parts of England with advantage, and called ash-mortar. It is prepared by slacking two bushels of fresh burnt

meagre lime, and mixing it accurately with three bushels of wood-ashes: the mass is to lie till it is cold, and is then to be well beaten: in this state it will keep a considerable time without injury, and even with advantage, provided it is thoroughly beaten twice or thrice before it is used.¹

The scales of black oxyd which are detached by hammering red-hot iron, and are therefore to be procured at the forges and blacksmiths' shops, have been long known as an excellent material in water cements, but we believe that Mr. Smeaton was the first person who made any accurate experiments on their efficacy compared with other substances. The scales being pulverized and sifted, and incorporated with the lime in the same manner as puzzolana, are found to produce a cement equally powerful with puzzolana mortar, if employed in the same quantity. Induced by the success of these experiments, Mr. S. substituted roasted iron ore for the scales, and found that this also gave to mortar the property of setting under water: it requires however to be used in greater proportions than either tarras or puzzolana: two bushels of argillaceous lime, two of iron ore, and one of sand, being mixed with the same care as we have already mentioned, produce 3.22 cubic feet of cement fully equal to tarras mortar. If the common white lime is made use of, it will be advisable to employ equal quantities of all the three ingredients.

Nothing more remains to be said on this part of the subject but a few words concerning the choice of the water by which the several ingredients of the cement are to be mingled together. River or pond water, where it can be had easily, is to be preferred to spring water, but for works exposed to the action of the sea, such as piers, light-houses, &c. it is usually more convenient, and equally advantageous in other respects to use salt water. The great point, and which is too often neglected, is not to put in too much of either one or the other: it is infinitely better to employ no more than is requisite to slack the lime, and so incorporate the materials at the expence of a little more labour than by a superfluity of water to bring the whole to the proper consistence without beating.

§ 3. *Malta or Maslich.*

Under this term we include those calcareous cements of a more complicated kind whose hardness appears to depend on the oily and mucilaginous substances that enter into their composition. The use of these is at present very limited, at least in Europe, but they were highly esteemed by the ancients, especially for stucco.

¹ Journ. de Phys. i. p. 370.

¹ Smeaton.

The Maltha of the Greeks seems to have been more simple than that employed by the Roman architects; at least we are informed that Panæ-nus, the brother of Phidias, lined the inside of the temple of Minerva, at Elis, with a stucco, in which the usual materials (sand and lime) were mixed up with milk instead of water, some saffron being also added to give it a yellow tinge. The Roman Maltha, according to Pliny,^k was prepared in the following manner. Take fresh burnt lime, slack it with wine, and beat it up very well in a mortar with hog's-lard and figs: this cement if well made is excessively tenacious, and in a short time becomes harder than stone: the surface to which it is to be applied is to be previously oiled in order to make it adhere. Another kind almost equally strong and considerably cheaper was prepared by beating up together fine slacked lime, pulverized iron scales, and bullock's blood. In the preparation of mastichs, as well as of every other kind of mortar, so much depends on the manipulation, and especially on the care which is taken to incorporate the ingredients by *long* beating, that those countries in which labour is of the least value possess in general the best mortar. Hence no doubt principally arises the unrivalled excellence of the mortar made by the Tunisiens and other inhabitants of the northern coast of Africa, which, according to Dr. Shaw, is prepared in the following manner. One measure of sand, two of wood ashes, and three of lime, being previously sifted, are mixed together, and sprinkled with a little water; after the mass has been beaten some time a little oil is added: the beating is carried on for three days successively, and as the evaporation in that hot climate is considerable, the cement is kept at the proper degree of softness by the alternate addition of very small quantities of water and oil. The cement being completed is applied in the usual manner, and speedily acquires a stony hardness. The last species of Maltha that we shall mention is the celebrated chunam of India, where it has been used from time immemorial. The method in which it is prepared at Madras is as follows.^l

Take 15 bushels of pit sand, and 15 bushels of stone lime, slack the latter with water, and when it has fallen to powder mix the two ingredients together, and let them remain untouched for three days. In the mean time dissolve 20 lbs. of molasses in water, boil a peck of gramm (a kind of pea) to a gelly; boil a peck of mirabolans also to a gelly, mix the three

liquors and incorporate part of the mixture very accurately with the lime and sand, so as to make a very fluid cement: some short tow is now to be well beaten into it, and it is then fit for use. The bricks are to be bedded in as thin a layer as possible of this mortar, and when the workmen leave off, though but for an hour, the part where they recommence working is to be well moistened with some of the above liquor before the application of any fresh mortar. When this is used for stucco, the white of four or five eggs, 4 oz. of butter, or sesamum oil, and a pint of butter-milk, are to be ground up with every half bushel of cement, and the mixture is to be applied immediately.

It is to be regretted that no experiments have as yet been instituted to ascertain the cause of the induration of calcareous cements: it is obviously not owing to the absorption of carbonic acid, because in numerous instances the cement hardens long before the lime is saturated: in the different kinds of maltha the lime combines with the albumen, mucilage, and oil, with which it is in contact, and in all probability takes up little or no carbonic acid, and if it is true that the lime in old mortar cannot, by burning, be reconverted into quicklime, it may reasonably be questioned whether, even in the simple calcareous cements, carbonic acid acts so important a part as is usually attributed to it.

CERUMEN, or *Ear Wax*.

This secretion is known to be a yellow glutinous substance, extremely bitter, which is always contained in greater or less quantity in the canal from the external ear to the tympanum. By the analysis of Vauquelin^m it appears to be considerably combustible, and largely soluble in alcohol; the residue not acted on by this liquor readily unites with alkalies. It appears to be composed of a fat oil resembling that of the bile; of an albuminous mucilage; and of a peculiar colouring matter, in which also the bitterness seems to reside. The quantity collected was too small for a more accurate examination.

The use of the ear-wax is not precisely known, but a due quantity of it seems essential to the sense of hearing. It is readily softened by strong soap and water, which forms a good injection to loosen it from the ears when it has collected in too large quantity, a very common cause of deafness.

CERUSSE, or *White Lead*, is a white oxyd of this metal prepared by the vapour of vinegar. See LEAD.

^k Hist. Nat. lib. ch. 53.

^l Phil. Trans. xxxvii. p. 231.

^m Fourcroy Syst. des Connoiss. Chim.

CERUSSE OF ANTIMONY is a perfect oxyd of antimony prepared by nitre. See ANTIMONY.

CHALCEDONY.*

Of this mineral there are two subspecies.

1. Subspecies. Common Chalcedony. *Ge-meiner Kalzedon*, Werner. *Calcedoine*, Fr. *Quartz agathe calcedoine*. Hauy.

The colour of chalcedony is bluish grey, passing into milk-white and smalt-blue; greenish grey, passing into apple and olive green; and yellowish grey, passing into wax and ochre-yellow, yellowish and blackish brown, and brownish black. Two or more of these colours are not unfrequently found in the same specimen, of which one generally forms the basis, while the others are distributed over its surface in dots, clouds, or stripes: when white and yellowish brown stripes, alternate with each other, the stone is called an *onyx*, and is highly esteemed by the lapidaries. The grey varieties, with thick prismatic distinct concretions, when transversely cut, present iridescent colours when held to the light, and have hence been named *rainbow chalcedony*. The translucent milk-white variety is called *cacholong*. The green and smalt-blue varieties are the rarest; the dark coloured ones when cut thin and held to a strong light, appear blood-red.

It is found massive, forming veins, in round balls of various sizes, called geodes, also kidney-shaped, botryoidal, stalactitic, mamillated, and impressed by various organized bodies, such as turbinites, &c.: certain crystalline forms, especially those of quartz have also been attributed to chalcedony, but these appear to be nothing more than crystals of quartz coated over with chalcedony. It possesses little or no lustre. Its fracture is perfectly even, passing into fine splintery and flat conchoidal. It breaks into indeterminate sharp-edged fragments. It frequently exhibits concentric lamellar or angular distinct concretions. It is commonly semitransparent; but the darker coloured varieties are only translucent. It is somewhat harder than flint, and by no means so easily broken. Sp. gr. 2.58 2.65. It is infusible *per se* before the blowpipe, but becomes milk-white and opaque. According to Bergman the chalcedony from Ferroe consists of

84. Silix

16. Alumine, and a little iron

100

It occurs in geodes and veins in Amygdaloid; also in veins accompanied by quartz, pyrites, &c. in porphyry. It was anciently procured from Chalcedon in lesser Asia, whence its name, but at present is found principally in Scotland and the adjoining islands, in Cornwall, Iceland, Saxony, Hungary, Piedmont, and various parts of Asiatic Russia.

2d Subspecies, Carnelian. *Karniol*, Werner. *Carnaline*, Fr.

The usual colour of this mineral is blood-red, whence it passes into flesh-red, reddish-white, milk-white, orange, and honey-yellow: two or more colours often occur in the same specimen, disposed in zones, stripes, and arborizations. It occurs in veins and rounded pieces; has a conchoidal fracture and a slight degree of lustre. In other respects it agrees with common chalcedony. The variety with alternate white and red stripes, is called *Sardonyx*. Carnelian is found in various parts of Europe, but the most beautiful and valuable pieces are brought from Arabia, and Surat, and Cambay in India. Carnelian from its beauty and hardness, has always been much sought after by lapidaries, some of the finest antique cameos are formed of it.

It is customary among modern mineralogists to place *agate* as an appendage to the species of chalcedony, since it is to this mineral that the former is indebted for its most striking characters, and because the coloured chalcedonies pass imperceptibly into agate.

Agate is a mixture of chalcedony, carnelian, jasper, hornstone, quartz, heliotrope, amethyst, and indurated lithomarga, aggregated into binary or more complex combinations. It has nevertheless several characters by which it may be distinguished from other minerals.

Although it consists of parts differing from each other in colour and transparency, yet these possess a certain uniformity of arrangement, and slide into each other by such nice gradations, as show them to have been all of simultaneous formation. As it differs in the colour of its constituent parts, so it does also in their transparency; it is never wholly opaque like jasper, nor transparent like quartz crystal: it takes a very high polish, and its opaker parts usually present the appearance of dots, eyes, veins, zones, clouds, bands, or ramifications.

It is found in the form of irregular rounded nodules, from the size of a pin's-head to more than a foot in diameter, or in veins or strata, and sometimes stalactitic. Several varieties of agate are distinguished by lapidaries. The finer

* Emmerling, Brochant, Kirwan, Hauy.

kinds consisting chiefly of chalcedony, carnelian, and heliotrope, are called oriental. In the banded or ribbon-agate, the colours are disposed in strait parallel lines or bands. In the fortification agate, the most beautiful of all the varieties, the colours are arranged in waved and angular parallel zones. The landscape or ruin agate represents rocks or buildings. The tube-agate is a congeries of hollow stactites of chalcedony filled with, and imbedded in carnelian, jasper, &c. The moss agate, called *Mocha stone*, from a corruption of the German mochs-stein (moss-stone) consists of chalcedony or carnelian, penetrated by arborescent iron ore, which, when the filaments are delicate, has a very beautiful appearance.

Agates are found for the most part in nodules in Amygdaloid, and sometimes in Gypsum: near the river Wolga they occur between strata of secondary lime-stone; and in Siberia certain rocky tracts consist of banks of pudding-stone, of which agate and chalcedony form the principal part.

The most beautiful agates that this island produces are called Scotch pebbles, and are found principally in the neighbourhood of Perth and Dunbar. The most celebrated however in Europe, are those of Oberstein in the Duchy of Deuxponts. Those of Siberia are eminently beautiful, but the most esteemed of all come from Ceylon and other parts of India.

Agate is cut into cameos or seal-stones, is hollowed into snuff-boxes, or sawn into thin plates for inlaying tables, and is applied to other ornamental purposes. The commoner kinds are made into mortars for the enameller and chemist, as from their hardness they are not liable to be materially abraded by pulverizing the hardest glass and stones in them. The coarsest fragments that are applicable to no other use are formed into the white gunflints, which are harder than common flint, and not so brittle.

CHALK. *Kreide*, Werner. *Craie*, Fr.

The colour of this mineral is yellowish white, more rarely snow-white or greyish white; when contaminated with iron it has more or less of an ochery tinge. It occurs generally in masses, sometimes disseminated, or investing other minerals. It is without lustre, is opaque, has a fine earthy fracture, and breaks into blunt edged angular fragments. It stains the fingers, gives a white streak, and when pure is very soft and almost friable. It has a meagre feel and adheres to the tongue. Sp. gr. about 2.3. It effervesces violently with acids. When mixed with iron it becomes both harder and heavier.

In a state of purity chalk appears to be composed only of lime, carbonic acid, and water, but a specimen analyzed by Mr. Kirwan afforded him

- 53. lime
- 42. carbonic acid
- 3. water
- 2. alumine

100

Chalk, where it is found at all, is the preponderating substance, and may therefore be considered as characterizing a peculiar species of mineral formation. It is perhaps the most recent of all the varieties of calcareous carbonat, it occurs in strata for the most part nearly horizontal, alternating with thin layers of flint nodules, and with the same irregularly dispersed through its substance: it contains in abundance the relics of marine organized bodies, such as echinites, gloiopetræ, pectinites, &c. and also not unfrequently the hard parts of amphibious and land animals, as the heads and vertebrae of crocodiles, and teeth of elephants. Chalk hills never rise to a higher elevation than three or four hundred feet, and are at once distinguishable by the smooth regularity of their outline, and their remarkable tendency to form cup-shaped concavities. Ridges of chalk, in England at least, are always bordered by parallel ranges of sand or sandstone, beneath and alternating with which are situated the beds of fullers earth. Chalk-hills are also singularly characterized by their dryness and their verdure: the most porous sandstone is scarcely so deficient in springs of water, and yet except upon almost perpendicular descents, the white surface of the chalk is uniformly covered with fine turf or wood.

The chalk-hills in England occupy a greater extent than in any other country, they run in a direction nearly from east to west parallel to each other, and separated by ranges of sandstone, and low tracts of gravel and clay. The most northern and loftiest range of chalk commences at the promontory of Flamborough-head, in Yorkshire, and proceeds westward for nearly 20 miles. In the county of Lincoln are some fragments of a ridge near Grantham. Two ridges traverse the midland counties, and reach as far west as the borders of Oxfordshire: these ridges are no where so conspicuous as in the county of Bedford, where they approach near to each other, being only separated by the Woburn and Ampthill range of sandstone. The country south of the Thames also contains two ridges,

the one commencing at the North and South Forelands, passing through the north of Kent, the middle of Surry, and the north of Hampshire, and including the North Downs of Bantstead, Epsom, &c.; the other commencing near Hastings and at the lofty promontory of Beachy-head, passes through Suffex and the south of Hampshire, into Dorsetshire, including the South Downs.

The north part of France also abounds in chalk: it is besides met with in some of the Danish islands in the Baltic, and in Poland.

The uses of chalk are very extensive: the more compact kinds are used as building stone, and are burnt to lime (nearly all the buildings in London being cemented with chalk-mortar): it is also largely employed in the polishing of metals and glass, in constructing moulds to cast metal in, by carpenters and others as a material to mark with, and by starch-makers and chemists to dry precipitates on, for which it is peculiarly qualified on account of the remarkable facility with which it absorbs water.

CHALK, *Spanish*. } See STEATITE.
CHALK, *French*. }

CHARCOAL. See CARBON.

CHEESE. See MILK.

CHERT. See HORNSTONE.

CHLORITE.^a

There are four sub-species of this mineral.

1. Earthy Chlorite, *Chloriterde*, Werner.

Its colour is intermediate between dark mountain green and blackish green: it is composed of minute somewhat shining scales, either loose or slightly coherent: it does not stain the fingers, but gives a shining green streak: it feels rather greasy, is light, and when breathed on, gives a strong argillaceous odour.

Earthy chlorite melts before the blow-pipe to a dark-coloured shining slag, which is attracted by the magnet. According to an analysis by Vauquelin, it consists of

8.	Magnesia
26.	Silex
18.5	Alumine
43.	Oxyd of iron
2.	Muriat of soda
2.	Water

99.5

It occurs for the most part in primitive mountains of argillaceous schistus mixed with quartz, common chlorite, calcareous spar, and micaceous iron ore. It is also contained in gra-

nular lime-stone and primitive sand-stone. By exposure to the air it decomposes into a yellow ochery mass.

It is found in Saxony, Switzerland, Norway, Sweden, Hungary, and North Wales.

2. Common Chlorite, *Gemeiner Chlorit*, Werner.

The colour of this mineral resembles that of the preceding, except that it is a little darker. It occurs in mass and disseminated, has a glistening lustre, and a fine foliated fracture passing into earthy. It is soft, gives a light-green streak, and has a greasy feel. Sp. gr. 2.83.

It consists, according to Höpfner, of

39	Magnesia
41	Silex
6	Alumine
1	Lime
10	Oxyd of iron

97

By the action of the blow-pipe it acquires a brownish-yellow colour.

It is generally found in metalliferous veins, but is also found in veins of quartz.

3. Chlorite-slate, *Chloritschiefer*, Werner.

Its colour is a dull green of various degrees of intensity from greenish-grey to greenish-black: it occurs only in mass; it has a glistening and greasy or resinous lustre. Its fracture is curved or waved foliated: those varieties that have the greatest degree of lustre are usually scaly foliated. When broken it flies into blunt-edged flaty fragments. It is opaque, is soft, has a greasy feel, and gives a mountain-green streak. Sp. gr. 2.98.

It does not melt *per se* before the blow-pipe, but by a continued heat becomes white.

Chlorite slate is one of the primitive rocks, and is generally found in layers alternating with argillaceous schistus, sometimes, though rarely with gneiss. It passes into micaceous schistus and hornblende slate, and often contains imbedded crystals of garnet or octohedral magnetic iron ore.

4. Foliated Chlorite, *Blättriger chlorit*, Werner.

The colour of this mineral is dark-green. It occurs in mass or disseminated, or crystallized in hexagonal tables, or six-sided prisms terminated by pyramids, the angles of which are rounded off so as to resemble a cylinder terminated by a cone. The surface of the crystals is streaked and glistening; its internal lustre is shining and pearly; its fracture is foliated, generally curved, and the laminae are in some

^a Emmerling. Haüy. Jameson.

degree flexible. It is translucent on the edges, is soft and easy frangible. It contains according to Lampadius,

35.	Silex
29.9	Magnesia
18.	Alumine
9.7	Oxyd of iron
2.7	Water

95.3

It occurs in the Duchy of Salzburg, and Mont St. Gothard, in Switzerland, accompanied by prismatic crystals of titanium; it has also been found in the Island of Jura in the Hebrides. It seems to be considered by Haüy as a variety of Mica.

CHROME.

Chrome is a metallic substance of a greyish white colour, extremely brittle, acidifiable with difficulty by nitric acid, and then capable of combining into a lemon-yellow salt with caustic potash. This salt being added in solution to nitrat of lead occasions a deep orange-red precipitate of chromated lead.

Chrome has hitherto been only found in the acid state combined with lead and with iron.^a

Sp. 1. Chromat of Lead; *Red Lead-spar*, Kirw. *Roths Bleyerz*, Werner. *Plomb rouge*, Broch. *Plomb Chromaté*, Haüy.

The colour of this mineral is aurora-red passing into hyacinth-red: it occurs very rarely in mafs, sometimes disseminated, but most commonly crystallized. Its primitive crystalline form is that of a rectangular prism divisible along the diagonals of its base into trihedral prisms: it is also found with two of the lateral edges of the prisms truncated, thus forming a six-sided prism, two of the faces of which are much wider than the rest; sometimes all the lateral edges are truncated, whence results an eight-sided prism. The crystals are of moderate size, adhering laterally to each other, and generally very imperfect and ill-defined: the lateral faces are slightly striated longitudinally, and have a brilliant external lustre. The fracture is fine-grained uneven, passing into conchoidal, and irregularly lamellar. It breaks into blunt-edged indeterminate fragments. It is translucent, passing into semitransparent, is brittle, easily frangible, and, when scraped, gives a yellowish orange coloured powder. Sp. gr. 6.02.

Chromat of lead when exposed to the blow-pipe crackles a little, and melts into a blackish slag: with borax it is in part reduced to the

metallic state, and communicates a green colour to the flux. The results of its analysis by Vauquelin were

63.96	Oxyd of lead
36.40	Chromic acid.

100.36

The only substances liable to be confounded with this mineral are realgar and red-silver; the first of these however differs from the chromat of lead in its inferior specific gravity, its volatility before the blow-pipe, and its arsenical odour when heated; the second is distinguished by its colour which is a pure red without any mixture of orange, and by its superior metallic lustre.

Chromat of lead has hitherto been found only in the gold mine of Berezof, to the north of Ekaterinenburg, on the eastern side of the Uralian mountains: it is thinly dispersed in a vein passing through gneiss and micaceous schistus, accompanied by quartz, galena, and auriferous pyrites. None of the crystallized varieties have been found for some years, in consequence of which they are now sold at a most enormous price, being valued at their weight in gold. The only use to which this substance has been applied is as a pigment: it is in high esteem among the Russian painters both on account of the unalterability and beauty of its colour.

Sp. 2. Chromat of iron. *Fer Chromaté*, Haüy and Broch.

The colour of this mineral is greyish or blackish-brown; it occurs in mafs; it possesses a slight degree of metallic lustre; its fracture is compact, uneven, sometimes imperfectly lamellar; when pulverized it is of an ash-coloured grey. It is sufficiently hard to scratch glass, is difficult to break, is opaque, and gives an argillaceous odour when breathed on. Sp. gr. 4.03.

It is infusible before the blow-pipe without addition, but with borax it melts into a beautiful green-coloured glass. It contains according to the analysis of Vauquelin,

43	Chromic acid
35	Oxyd of iron
20	Alumine
2	Silex

100

Chromat of iron is said to have been found in Siberia; it has also been discovered in France near Gassin, in the department of Var, forming

^a Haüy. Brochant.

nodules and veins in serpentine; some of the nodules are nearly a cubic yard in magnitude.

The method of analysing the chromat of lead is very simple. Vauquelin has pointed out two ways,^b both of which we shall mention, only observing that the last is upon the whole the most satisfactory.

Take one part of finely pulverized chromat of lead, three parts of perfectly saturated carbonat of potash, and forty parts of water, and boil the mixture together for the space of an hour. As soon as the substances begin to act on each other, a brisk effervescence will take place, the orange colour of the lead will begin to change to brick-red, and finally when the effervescence has ceased, there will remain at the bottom of the vessel a powder of a dirty yellow colour consisting of carbonat and chromat of lead, covered by a clear liquor of a bright golden yellow, which is chromat of potash. The liquor being poured off, and the powder well washed, some very dilute nitric acid is to be poured on the powder till it ceases to effervesce; the colourless solution thus obtained is nitrat of lead, while the undecomposed residue of chromated lead will remain unaltered, and is afterwards to be decomposed by a second digestion with thrice its weight of carbonated potash. The nitric solutions of lead being mixed together are to be decomposed by sulphat of soda, and the lead contained in the ore is to be estimated from the sulphat of lead thus procured. The alkaline solutions of chromic acid being mixed with the washings, are to be mixed with weak nitric acid as long as any carbonic acid from the undecomposed carbonat of potash, is given out, and the liquor by subsequent evaporation and cooling deposits crystals of chromat of potash mixed with nitre.

The second method of decomposing this substance is, to digest together, at a moderate temperature, equal weights of chromat of lead very finely pulverized, strong and pure muriatic acid, and distilled water, taking care to stir the mixture from time to time. The chromat of lead will be decomposed, and will change to a white colour, being converted for the most part to muriat of lead. When the acid has ceased to act, the liquor must be poured off, and fresh muriatic acid (diluted as before with water) to the amount of about one-fourth of the former quantity is to be digested with the residue till no more orange-coloured grains appear among the white muriat. The liquor being added to the former, together with the washings, the

whole after being heated is to be placed for a few days in a cool place, that the small quantity of muriated lead, which it holds, may be deposited; when this is removed some oxyd of silver, precipitated from its solution in nitric acid by caustic potash, is to be added very gradually till the last portions acquire a red purple colour, thus the whole of the muriatic acid will be got rid of, and the liquors will contain only chromic acid, which, by slow evaporation, is deposited in small prismatic ruby-red crystals.

The decomposition of chromat of iron is not effected by any means so easily as of chromated lead. The action of muriatic or oxymuriatic acid upon it is very slow and imperfect, nor is a boiling solution of either pure or carbonated potash attended with any better success. The most effectual way of proceeding according to Tassaert and Vauquelin^c is to fuse in a platina crucible the finely pounded ore with an equal weight of caustic potash, then to separate all that is soluble in water, and treat the residue with hot muriatic acid. By the alternate use of these menstrua for six or seven times each, the whole of the ore will be taken up and dissolved. The muriatic solution being evaporated nearly to dryness, and then left to cool, will become gelatinous, thus announcing the presence of filix which may be obtained by redissolving the gelly in water, in consequence of which the filix will be precipitated; the clear liquor being then treated with ammonia the iron will be obtained in the state of oxyd. The muriatic solution being thus exhausted, the alkaline solution is to be carefully neutralized by nitric acid, by which means the alumine will be precipitated, and nothing will be left in the liquor but chromat of potash and nitre, from which the chromic acid may be obtained pure by adding nitrat of lead till no further precipitate takes place, and then treating the chromat of lead thus formed with muriatic acid, as mentioned above.

Chromic acid is of an orange red colour, and a pungent metallic taste; it is very soluble in water, and, by gentle evaporation, crystallizes in lengthened prisms. Like other acids it combines with the salifiable bases, whence results a genus of compound salts called *chromats*, the chief of which we shall proceed to describe.

Chromat of Barytes is formed by mixing together the aqueous solutions of barytes and chromic acid: it appears as a pale lemon-yellow precipitate, is sparingly soluble in water, and has no perceptible taste. When heated, it gives out oxygen gas, and assumes a green colour.

^b Journal des Mines, No. 34, p. 744.

^c Ibid. No. 55, p. 522.

Chromat of Lime is prepared like the preceding: by adding the liquid acid to lime-water, an orange-yellow precipitate falls down, differing from the chromat of barytes only in being less soluble, and in a somewhat different order of affinities.

The carbonated *alkalies* are decomposed with effervescence by chromic acid, forming very soluble and crystallizable salts of a lemon-yellow colour. The chromat of ammonia is destroyed by a red-heat, the alkaline base being decomposed, and deoxygenating the acid so that only a green oxyd of chrome remains behind. The alkaline chromats are decomposable with abstraction of their acid by barytes, lime, and strontian, and with abstraction of their base by the mineral acids: when added to any of the soluble metallic salts a double decomposition takes place, and the chromated metal is precipitated in form of a coloured powder; mercury gives a vermillion-red precipitate, silver a carmine-red, lead an orange-yellow, tin a green, &c.

Chromic acid appears to be very easily reducible to the state of oxyd, in which state it is generally of a green colour. Thus, when heated on charcoal before the blow-pipe, it first boils, and when the moisture is evaporated, a green pulverulent infusible oxyd remains. By fusion with borax and glass of phosphorus it affords vitreous globules of a bright emerald green. With tannin chromic acid forms an insoluble yellowish-brown flocculent sediment, and with hydro-sulphuret of potash a brownish-green one.

Muriatic and chromic acids when heated together in a retort occasion a considerable effervescence; part of the muriatic acid is converted into oxymuriatic acid which flies off, and the chromic acid is changed into the green oxyd. Ether or alcohol when heated for a few seconds with this acid produce a similar effect; as does also muriat of tin, the same metal in the reguline state, iron, zinc, and most of the other metallic substances. Even light will decompose chromic acid, for a paper wetted by it, and exposed during a few days to the sun, assumes a permanent green colour.

In order to reduce chromic acid to a regulus, it is sufficient to heat it strongly in a crucible lined with charcoal, the result will be a brittle, brilliant, greyish white metallic button amounting to about 67 *per cent.* of the acid employed. At a high temperature it assumes the form of feathery crystals. A fragment of this metal when exposed to the blow-pipe, first tarnishes, and then

acquires a thin coating of greenish oxyd. When finely pulverized, and treated with concentrated boiling nitric acid, it is oxydated with extreme difficulty, and gives the acid a light bluish-green colour; by repeated abstractions it is at length compleatly acidified, and then exhibits exactly the same characters as the native acid.

Chrome on account of its scarcity, and the short time that it has been known has not yet been applied to any use; it is probably however capable of furnishing some fine pigments to the painter and enameller: in particular it will tinge glass with a true EMERALD green; the colouring matter of this beautiful gem having been recently proved to be this very metallic oxyd.

CHRYSOBERYL^a. *Cymophane* of Haüy. *Oriental* and *opalescent Chrysolite* of some naturalists.

The colour of this mineral is asparagus-green, passing into greenish-white on one side, and on the other through olive green into yellowish-grey, and sometimes reddish-brown. It generally exhibits a bluish milky light, undulating within the crystals. It is usually met with in small rounded pieces, but occasionally possesses a well marked crystalline figure. Its primitive form is that of a rectangular parallelepiped, and the figures which it has hitherto been observed to affect are,

1. A short, regular hexahedral prism or table.
2. The same with a truncated hexahedral pyramid raised upon each base.

The surface of the rounded pieces is somewhat rough, and generally reflects glittering variegated colours. The crystals possess a double refraction, are externally shining, and very brilliant internally, so that when polished it may often be confounded with the yellow diamond. The fracture of chrysoberyl is perfectly conchoidal; its fragments are indeterminately angular, and sharp-edged; its hardness is superior to that of quartz; its sp. gr. is = 3.7.

It is infusible *per se* before the blow-pipe; and consists, according to the analysis of Klaproth^b, of Alumine . 71.5.

Lime . . . 6.

Oxyd of iron . 1.5

Silex . . . 18.

97.5

Loss . 3.

100.

It is procured chiefly from Brazil, where it

^a Emmerling. Brochant. Haüy. Jameson. ^b Analyt. Ess. I. p. 85.

accompanies the topazes: it has also been discovered by Count Bournon in sand from the island of Ceylon, together with rubies and sapphires. A few specimens have been brought from Nertschinsk in Siberia. It is however upon the whole a very rare mineral, and from its hardness and lustre is considerably valued by jewellers.

CHRYSOLEITE. *Peridot* of Haüy.

The principal colour of this mineral is pistachia-green, passing into brownish-olive. It occurs in angular or rounded fragments, or crystallized. Its primitive form is a strait prism with rectangular bases, the other varieties of crystallization under which it appears are

1. An octagonal prism terminated at each extremity by six faces oblique and one horizontal.

2. The same terminated by eight oblique faces corresponding to the sides of the prism, and one horizontal.

3. A ten-sided prism terminated by six oblique faces and one horizontal.

4. A twelve-sided prism terminated by eight oblique faces and one horizontal.

In all the varieties except the third those faces in the prism which are the remains of the long sides of the original prism are deeply striated, while those which are the remains of the short sides are remarkably smooth. The internal lustre of the crystals is brilliant and vitreous. Its fracture is perfectly conchoidal; the fragments are indeterminately sharp-edged. It is perfectly transparent, and possesses a double refraction in a very remarkable degree. Its hardness exceeds that of glass. Sp. gr. = 3.34.

It is infusible *per se* before the blow-pipe, but with borax forms a transparent green glass.

It has been analyzed by Klaproth^a and Vauquelin^b with the following results.

	Klapr.	Vauq.
Silex - -	39.	38.
Magnesia -	43.5	50.5
Oxyd of iron	19.	9.5
	<u>101.5</u>	<u>98.0</u>

It is not known with any certainty whence the chrysolite is procured: Upper Egypt is said to be one of the countries which afford it, and a few come to the jewellers of Europe from the East Indies. It ranks among the gems, but its softness and unattractive tone of colour, especially when the yellow predominates, make it of little value.

^a Analyt. Ess. i. p. 91.

^b Journ. des Mines, No. 24.

CHRYSOLEITE BRASILIAN, } See
ORIENTAL, } **CHRYSO-**
OPALESCENT, } **BERYL.**
CHRYSOLEITE VOLCANIC. See OLIVIN.
CHRYSOLEITE VESUVIAN. See VE-

SUVIAN.

CHRYSOPAL. See CHRYSOBERYL.

CHRYSOPRASE. *Quartz-agathe prase.* Haüy.

The colour of this mineral is apple-green, passing into grass and olive-green and greenish-grey. It is found in mass, in angular fragments and thick plates. Internally it exhibits a slight degree of lustre. Its fracture is even, passing sometimes into fine splintery and flat conchoidal, with indeterminate sharp-edged fragments. Its hardness is somewhat less than that of Chalcedony. Sp. gr. 3.25.

Before the blow-pipe chrysoprase becomes opaque and colourless, but is infusible *per se*. It has been analysed with great accuracy by Klaproth^c, and appears to consist of

Silex - -	96.16
Lime - -	0.83
Oxyd of Nickel	1.0

97.99

It has hitherto been found only at Kosmutz in Lower Silesia, imbedded in serpentine, along with quartz, opal, chalcedony, &c. It passes into hornstone and chalcedony, and appears to differ from this last in little else than colour.

When kept long in a warm and dry situation it loses the greatest part of its colour. The apple-green variety is in some estimation among jewellers, and is cut into stones for rings.

CHYLE. The food of animals after it has undergone digestion in the stomach passes into the small intestines, in which the alimentary part is separated, and from which it is absorbed or sucked by small vessels called the *lacteals*, that convey it through a circuitous course finally into two veins, where it mixes with, and becomes blood.

Chyle therefore is the last change that food undergoes previous to its conversion into blood, and its analysis would be scarcely less interesting than that of blood itself, could it be collected conveniently, and in sufficient quantity. Hitherto only a few desultory experiments have been made, which are collected by Haller.^d

By these we learn that chyle is a milky white fluid, of an agreeable sub-saline taste, lighter than the serum of blood, or even than water,

^c Analyt. Ess. i. p. 420.

^d Elem. Physiolog. vol. 7.

on the surface of which it swims like cream, readily coagulating like blood by simple rest and extravasation, and appears to be composed of water, of an oily substance consisting of globules, of a heavier matter like cheese which remains at the bottom after coagulation, and of some earth. Chyle readily turns sour by keeping, but gives no sign of acidity when fresh. The nature of the aliment makes some, though a very small change in the sensible qualities of chyle. Thus it is sometimes tinged when colouring matter has been taken into the stomach.

It does not however shew any marks of containing iron, even when the animal has been in the habit of taking this metal.

CIMOLITE^a of Klaproth. *Cimolia* of Pliny.

The colour of this mineral is a light greyish-white, inclining to pearl-grey; but by exposure to the air it acquires a reddish tint. It occurs in mass, forming large strata; its fracture is earthy, uneven, and its texture more or less flaty. It is opaque, of a greasy lustre, and may be scraped with a knife like steatite. It adheres firmly to the tongue, stains the fingers in some degree, and, though soft, is very tough, and difficultly pulverizable. Sp. gr. = 2.0.

When exposed to the action of the blow-pipe *per se*, it becomes at first of a dark grey colour, but afterwards recovers its whiteness with little or no alteration: with microcosmic salt it runs into a colourless globule, with borax it forms a light brown glass. Its component parts are

Silex	-	-	63
Alumine	-	-	23
Oxyd of iron	-	-	1.25
Water	-	-	12
			—
			99.25

It abounds in the island of Cimola (whence its name) now called Argentiera, and was highly valued by the Greeks and Romans for its detergent properties; at present its use is almost entirely confined to the inhabitants of the island. When triturated with a little water it forms a soft pap-like mass, and being applied in this state to silk or woollen cloth, and allowed to dry on, it absorbs all the grease which they may contain, like fullers' earth, but more effectually, and is again discharged by a slight washing, leaving the cloth restored to its original lustre.

CINNABAR. See MERCURY.

CINNABAR, Native. See MERCURY, Ores of.

CIRCON. See ZIRCON.

CITRIC ACID. *Acid of Lemons. Zitronensaure, G.*

Lemon juice is known universally to be one of the sourest, and at the same time the most agreeable of all the native vegetable liquors. It is prepared simply by squeezing the fruit, and straining through linen or any other loose filter. In Sicily, Italy, Majorca, and many other parts of the Mediterranean, lemon juice forms an important article of commerce. It is procured simply by peeling the fruit, slicing it, and putting it in a large press with a cloth or hair strainer.^a The juice, which comes out very turbid, is placed for a day in cellars and then strained, and put in jars with narrow necks well cemented up, the top of the juice being generally covered with a little oil, the better to defend it from the action of the air. Many of the presses will squeeze six thousand lemons at once.

Lemon juice is a natural mixture, about the specific gravity of, 1.034, composed of much water, of insipid vegetable mucilage, of extractive matter, of a slight portion of something that gives an astringent taste, of a little malic acid, and lastly of that peculiar acid, which, from its being contained more copiously in this fruit than in any other, is called the *citric acid*. The proportions of these ingredients must of course vary according to the degree of ripeness,^b the season, and the like, but on an average according to Proust, 576 grains of the fresh juice lose by evaporation 528 grains, which is the watery part; and of the remaining 48 grains about 30 grains are the pure citric acid, and the remainder is chiefly mucilage and extract. On account of these two latter ingredients, lemon-juice sooner or later, according to the temperature, spoils by keeping, becomes mouldy, undergoes an imperfect fermentation, and at last totally loses its acidity, acquiring a flat musty taste.

To prevent this destruction of the acid for which alone this juice is valuable, many methods of preservation have been devised, all of which answer to a certain degree, but none of them perfectly, except that of separating the acid in a crystallized form by means which will be presently mentioned. It should be observed that of the mucilage and the extractive matter, (the two materials which principally contribute to spoiling the juice) the former alone is separable by the ordinary methods of clarification, but the extract adheres to the acid with the greatest obstinacy, and it is this which hinders it from

^a Analyt. Ess. i. p. 248.

^b Murray, Apparatus Medic. vol. iii.

^c Jour. de Phys. tom. lii.

crystallizing when evaporated nearly to dryness.

Lemon-juice is clarified partly by being put for a day or two in a cold cellar, remaining perfectly at rest. Much of the mucilage then subsides, and the clear juice poured off, bottled, and carefully corked, will then keep for a considerable time. It is better if briskly boiled for a minute or two before it is put aside to clarify, but this somewhat impairs the flavour, and gives one that is not agreeable. In the Mediterranean, oil is poured over it to prevent the action of the air, which has a temporary effect, but after a while the juice beneath becomes muddy, bitter, mouldy, and besides gets a rank taste from the oil. Concentration by freezing is sometimes used with some success. If the mucilage is first separated as much as may be by standing in a cool place, and the clear juice then exposed to a cold of from 23° to 26° the watery part alone freezes, and the remaining unfrozen liquor, of course, contains the acid in a condensed state. By continuing to remove the ice, till it begins to grow sour from the acid itself freezing, lemon juice may be concentrated to about one-eighth of its former bulk, and is then clear, intensely sour, and will keep in a cool climate for several years unaltered.^c Still however the extract entirely remains and part of the mucilage, and therefore in tropical climates even this concentrated juice spoils in no great length of time,^d besides the capital defect in the utility of the process, that the cold which it requires can never be obtained naturally in the countries where the fruit grows, and at the season in which it is most likely to spoil.

Sometimes certain mixtures are added to lemon juice to preserve it. Forster found in Cook's Voyage to the South Pole that the juice mixed with a fifth part of brandy or rum, in well closed casks, kept very well for thirty-two months. Brugnatelli^e proposes to clarify the juice by alcohol. Fresh lemon juice was mixed with some strong alcohol and bottled. In a few days a slimy mucilage had separated, and the liquor filtered through paper, contained the purified juice with alcohol, which last may be separated by evaporation. But it is obvious that this only very partially clarifies the juice, for the clear liquor, evaporated slowly to dryness, gives no crystals, but only a sour extract. Besides, the expense forbids its being used in the great way. Some persons add sulphuric or some other mineral acid to the juice, partly to preserve and partly to adulterate it. The juice is

indeed kept a long time from moulding by this addition, but the adulteration is often a serious inconvenience and loss. Evaporation is certainly the best method of preserving the juice in hot climates in its natural state, that can be practised in the large way. This juice cannot be purified like vinegar by distillation, for, being less volatile than water, it will not rise in vapour with a heat less than will decompose it; but if the fresh juice simply strained be exposed to a very gentle heat, the greater part of the water flies off without carrying away any of the acid, and when the liquor has nearly a syrupy consistence (before it acquires a burnt taste), it is then intensely sour, and will keep in bottles for many years, with very little alteration, and even retaining much of its original flavour. This inspissated juice or *Rob of Lemons*, as it is called, if intended for the table, may be immediately mixed with dry white sugar, which is known to preserve all vegetable matter from corruption, and it will then keep for almost any length of time unimpaired, and is excellent for sea voyages and domestic use. In hot climates the heat of the sun is made to assist considerably in the evaporation.

But the pure citric acid cannot be obtained by such simple methods, but a double process of chemical affinity is required, first, by adding an intermede to separate it from the other parts of the juice, and next to obtain it free from this addition in its crystallized form. This very ingenious process was discovered by Scheele^f, and since has been followed by all succeeding chemists, with only a slight variation in the proportions and minutiae of the process. The intermede which this admirable chemist used was lime added in the form of chalk, the same that he had before employed for a similar purpose in preparing the concrete acid of *Tartar*.

The mode he recommends is in a few words the following: Saturate boiling lemon juice with chalk in powder added gradually, till no more effervescence arises. The compound thence arising is a grey insoluble mass, the citrat of lime, which readily settles, leaving the mucilage, extract, and other ingredients of the juice in the supernatant liquor, which is thrown away, and the calcareous precipitate well washed with cold water till it is colourless. Then add to the precipitate a quantity of dilute sulphuric acid, diluted with ten times its bulk of water, and equal in weight to the chalk used, and boil for a few minutes. This by stronger affinity unites with the lime, forming a sulphat of lime

^a Georgi from the Acta Soc. Petropol.

^b Proust.

^c Annali di. Chemia, vol. ii. Ph. Mag. vol. ii.

^d Essays.

equally insoluble with the citrat, whilst the citric acid, now set free, remains dissolved in the clear liquor, and by due evaporation may be procured pure, and in large crystals. The sulphuric acid should be a little in excess to engage all the lime, otherwise the acid will not crystallize.

Such is the process of this excellent chemist, but as the preparation of this acid has lately become an object of some importance in manufacture, it may be of advantage to compare the particulars of the process as given by different chemists.

In preparing citric acid in the great way, M. Dizé^a mentions the following particulars. After the citrat of lime has been decomposed by the sulphuric acid, cold water assisted by stirring is sufficient to wash out all the citric acid adhering to the sulphat of lime. This is of use both as saving fuel and as less of the calcareous sulphat is dissolved. Much however is still contained in the clear liquor, which in fact is a mixture of citric acid with the excess of sulphuric acid which it is necessary to add, and sulphat of lime held in solution. This liquor may be evaporated at a heat of boiling water. It is a clear light yellow. As the bulk of liquid diminishes, the sulphat of lime falls down, and it is of use to suspend the evaporation once or twice for some hours, that by cooling the whole of the sulphat may be deposited. Towards the end, the liquor becomes blackish owing to the sulphuric acid becoming concentrated, and acting partly perhaps on the acid itself, and partly as the author imagines, on a portion of extractive matter, which subsides along with the citrat of lime, and which he thinks it is necessary to destroy in this manner before the citric acid will crystallize. This acid is so very soluble that the evaporation must be pushed to a very thick syrupy consistence before the crystals will separate. They are at first black and dirty. By re-solution in cold water (of which a small quantity will suffice) by filtration, and a second evaporation, they become yellow and more regular. A third crystallization seems necessary to make them white and pure. As there is much waste

in these operations, the foul portion which will not pass the filter should be evaporated and treated as before.

Scheele has well remarked (and all other chemists have found the same) that an excess of sulphuric acid is required. M. Dizé supposes the peculiar use of this excess to be to destroy the remaining extractive matter, the existence of which he endeavours to prove by the proportions of ingredients required, and their products. One hundred pounds of the lemon juice he found to require for saturation 6.25 lb. of chalk, and to produce as much as 20 lb. of citrat of lime. On the other hand he found the crystallized citric acid to require its own weight of chalk for saturation, and to produce a quantity of citrat of lime equal to three-fourths of the weight of the two ingredients, the loss being chiefly carbonic acid. Hence he concludes that 100 lb. of fresh juice contains 6.25 lb. of the pure acid (that is equal in weight to the chalk required), and that the citrat of lime thence resulting if pure, ought to be no more than 9.378 lb. (being three-fourths of the sum of the weight of the chalk, and the supposed quantity of pure acid). But as it is really 20 lb. even after washing, he supposes this enormous difference to be made up by extractive matter precipitated along with the citrat of lime, and adhering to it. However the results of the experiments of other chemists do not give this difference, though they agree tolerably in other particulars. M. Dizé does not specify the quantity of crystallized acid actually obtained from a given quantity of juice.

Westrumb^b saturated 4 lb. of fresh lemon juice, simply strained, with 3 ounces of chalk, and obtained 5 oz. and 1 dram of citrat of lime, which, decomposed with 23 drams of strong sulphuric acid diluted with about ten times its bulk of water, gave by due evaporation 2½ ounces of crystallized acid a little foul, which lost one dram by a second crystallization.

Professor Proust has examined the same process.^c The ingredients and products given by those three chemists, reduced to the same proportion, are as follows:

^a Journ. de Phys.

^b Leonhardi in Macquers Worterbuch Art. Citronensaure.

^c Journ. de Phys.

Lemon Juice	Chalk	Citrat of Lime	Citric Acid in crystals	Citric Acid
100lb. requires	4.25lb. and produces	7.51 lb. yields	4.38lb. and contains	4.74lb. <i>Proust.</i>
for	by	by	by	
— saturation	4.65— precipitation	8.0 — evaporation	3.90— estimation	— <i>Westrumb.</i>
—	6.25—	20.	—	6.25— <i>Dizé.</i>
Cryst. Citric A.				
6.25	6.25—	9.375		D°

With regard to the proportions given by Proust, it is to be observed that only 7.51 of citrat of lime was actually precipitated, but by evaporation of the liquor he obtained about $\frac{1}{4}$ additional, or .54lb. The crystallized acid was obtained from a known quantity of the washed citrat of lime, 6 ounces of the latter giving $3\frac{1}{2}$ of the acid, hence 7.51 lb. would yield 4.38 lb. the .54lb. of the citrat procured by evaporation would therefore yield .315 of the crystallized acid, which, added to 4.38 gives 4.695 for the quantity of acid, exclusive of the small portion left in the last liquor after all the crystals have been removed, which the author estimates at a little more than $\frac{1}{100}$ of the quantity obtained, or in the present instance about .044, making a total of 4.74 of solid acid in 100 of the fresh juice.

The quantity of sulphuric acid required for the decomposition of the citrat is variously estimated, and as an excess of it is requisite, at least as much of the concentrated acid as will be equal to the chalk employed may be used, diluting it with about ten times its bulk of water. In this preparation therefore as the strength of the lemon juice is uncertain, and, as it would appear, the product of citrat of lime equally so, and troublesome to estimate, the quantity of chalk used seems the only proper guide to determine that of the sulphuric acid demanded, and the probable yield of citric acid. Therefore the chalk should be weighed, and the quantity used should be noted, which should be a little more than to saturation to engage the whole of the citric acid. If a portion of the same chalk be previously and separately mixed with some of the sulphuric acid intended to be used, and the quantity required for saturation be observed, it will furnish a still better guide for the second part of the process than that of using equal weights of chalk and acid. The clear supernatant liquor contains, besides the mucilage and extract, a portion of *malat* of lime in solution, lemon juice containing a small quantity of the malic acid. This calcareous

salt is precipitated by alcohol, if the liquor is concentrated by evaporation. A minute portion of gallic acid also appears in lemon juice by the test of iron, the mixture turning of a brown red after being saturated with an alkali.

To separate the citric acid completely from the lime, by the sulphuric in the second step of the process, Proust recommends boiling the whole for about five or ten minutes. The difficulty of separating all the sulphat of lime and extract from the disengaged citric acid, and of procuring clear regular crystals has already been mentioned. A little alcohol added towards the end of the first evaporation, and subsidence for some hours greatly assists this separation, and in the perfection of the crystals.

Richter gives another process for preparing the citric acid,^k which may be mentioned, though it does not appear that it is much used. Saturate lemon juice with carbonat of potash, then add sufficient acetited lead. A copious white precipitate appears, which is the citrat of lead. When no more falls down, wash the precipitate, digest with dilute sulphuric acid (as in the former process) to disengage the citric acid, evaporate the liquor to a thick consistence, add a few drops of nitric acid, and crystallize.

The theory of this operation is the same as in the former instance, substituting lead for lime, and with this difference that the lemon juice must first be saturated with alkali that the acetite of lead may be decomposed by *double* affinity by the citrat of potash, and to prevent an excess of acid by which the citrat of lead is rendered very soluble, though without such an excess it is scarcely dissolved in any sensible degree. Where this acid is used for the table the introduction of so dangerous a metal as lead, particularly in its acid combinations, is a serious objection, and for manufacture it appears more expensive than in Scheele's method.

Lemon juice when imported in this state is not unfrequently adulterated with some strong and cheaper acid. The sulphuric is most to be suspected. It is detected in the following way;

^k Gren. Handb. der Chim.

put some of the juice in a glass, and add a solution of acetite of lead. This will produce a copious white sediment in any case; after which add some drops of strong nitric acid. If the juice contained no sulphuric acid the white precipitate will be redissolved, and the liquor become again clear, the citrat of lead and malat (of which a small portion will also be formed) being readily soluble in nitric acid, but if the juice was mixed with sulphuric acid the sulphat of lead will remain at the bottom. If this is collected, washed, and dried, the quantity of sulphuric acid may be estimated from the known proportions of this salt. See *Lead*.

Pure citric acid crystallizes according to Lowitz¹ in alum-shaped crystals, consisting of two 4-sided pyramids joined base to base, or, sometimes, according to Dizé, in rhomboidal prisms. Its taste is intensely sour, and, when diluted, very grateful to the palate. It is very soluble in water, one ounce of distilled water at a moderate heat dissolving $1\frac{1}{4}$ ounce of the crystallized acid, and producing 30 degrees of cold by the mixture. In a boiling heat water dissolves twice its weight of the acid. The crystals are not deliquescent. Distilled *per se* the products are an empyreumatic acid phlegm, carburetted hydrogen gas, and carbonic acid. It seems to be composed of carbon and hydrogen with oxygen in unknown proportions.

If this acid is boiled with a small portion of nitric acid, much nitrous gas is given out, and the liquor evaporated and crystallized yields some oxalic acid. A greater proportion of nitric acid converts the whole into acetic acid, as it appears, without passing through the intermediate state of the oxalic. Thus Westrumb obtained half a dram of oxalic acid from one dram of citric acid with 200 grains of the nitric: with 300 grains only $\frac{1}{4}$ of a dram; and with 600 grains not an atom.

Vauquelin asserts that this acid may be obtained by passing oxymuriatic acid gas through gum arabic in water for a considerable time.^m

The culinary uses of lemon juice are well known. The concrete citric acid may be often substituted for the juice with advantage where the latter is not conveniently procurable, but it is to be observed that none of the peculiar flavour of the fruit so agreeable in the fresh lemon passes into the solid acid, which is merely sour, and without any particular astringency.

The use to which this acid has lately been put in manufacture is as a *discharger* of colour in calico-printing: the white figured parts of

coloured patterns prepared with iron colours being produced with great clearness and effect by this acid. It is not absolutely necessary to crystallize the acid for this purpose but only to concentrate it. The mineral acids answer equally as dischargers, but when sufficiently strong to do this effectually, they injure the texture of the cotton.

CITRATS. Of the salts formed by this acid with alkaline, earthy, and metallic bases, only a few deserve particular mention.

Citrat of Potash. This has long been known merely as a mixture in medicine under the name Riverius's salt. About 12 to 16 parts of lemon juice will saturate one of common carbonat of potash. To prepare it more accurately according to Vauquelin,^a 36 parts of the crystallized acid dissolved in water, require for saturation 61 parts of crystallized carbonat of potash. This salt crystallizes, though with difficulty, and is very deliquescent: 100 parts contain about 55.5 of acid, and 44.5 of alkali. It is decomposed by barytes and lime.

Citrat of Soda. This is a very soluble crystallizable salt. According to Vauquelin, 36 parts of acid require 42 of dry carbonat of soda, so that 100 parts of the citrat of soda consists of 60.7 of citric acid, and 39.3 of soda.

Citrat of Ammonia. Thirty-six parts of citric acid saturate 44 of carbonat of ammonia. Hence 100 parts of the salt contain 62 of acid, and 38 of ammonia. It is with difficulty crystallized, and is very soluble.

Citrat of Barytes. A hundred parts of this salt consists of equal weights of citric acid and barytes. When barytic water is poured into citric acid, dissolved in water, a precipitate is formed, which immediately is redissolved. But when approaching the point of saturation the barytic citrat is deposited in quantity, at first pulverulent, afterwards in fine clustered crystalline needles.

Citrat of Magnesia. Thirty-six parts of the acid require for saturation 40 parts of carbonat of magnesia, and 100 parts of the salt contain 33.34 of magnesia, and 66.66 of acid. This is not crystallizable, but when nearly evaporated to dryness, the salt rises in mushroom-like knobs, white and opaque.

Citrat of Lime. This is the best known of the earthy citrats, being formed, as already mentioned, in the preparation of the citric acid. It is but sparingly soluble in pure water, and the solution has very little taste. But an excess of acid renders it extremely soluble; 100

¹ Gren's Handb.

^a Ann. Chim. tom 6.

parts of citric acid, mixed with sufficient water boiling hot, dissolving 50 parts of the citrat of lime.^b According to Vauquelin, 24 parts of the acid are saturated by 18 of calcareous spar. Hence 100 parts of the citrat of lime contain 37.34 of lime, and 62.66 of acid. Proust found that 100 parts of the citrat washed and dried, left by calcination 31.5 of lime, and hence the remaining 68.5 must be citric acid with water in undetermined proportions. Dizé found that the acid required an equal weight of pure chalk for saturation, hence (supposing the chalk to contain 53 per cent. of lime) 100 parts of the dry citrat perfectly free from extraneous matter, will consist of about 65.4 of acid, and 34.6 of earth. This salt kept under water in a warm place soon grows mouldy, the acid is decomposed, and the water is covered with a crust of carbonat of lime. Citrat of lime is decomposed by the oxalic acid, or the oxalat of potash.

Metallic Citrats. These have been but little examined. The acid dissolves zinc and iron readily, and most of the oxyds of the other metals. It decomposes acetite of lead, as already mentioned, and the citrat of lead is insoluble in water without an excess of acid. Citrat of mercury is formed by adding this acid to the nitrat or acetite of mercury. The salt is a flakey precipitate of a brick-dust red.

The affinities of the citric acid appear to be in the following order.

Barytes, lime, potash, soda, strontian, magnesia, ammonia, and alumine. The comparative affinities of the metallic oxyds have not yet been determined.

CLARIFICATION is the separation by chemical means of any liquid from substances suspended in it, and rendering it turbid. If a difference can be made between clarification and *filtration*, it is that the latter is effected by mere mechanical means, but the former either by heat or by certain additions, the action of which may be considered as chiefly chemical. A few practical observations belong to both these articles.

The liquors subjected to clarification are almost without exception those animal or vegetable juices, in which the matter that renders them turbid is so nearly of the same specific gravity with the liquor itself that mere rest will not effect a separation. In these too the liquid is generally rendered thicker than usual by holding in solution much mucilage, which further entangles the turbid matter, and prevents it from sinking. Hence it is that vinous fermentation has so powerful an effect as a cla-

rifier, (wine being much more limpid than the grape or other fruit juice of which it is made) since this process always implies the destruction of a portion of saccharine mucilage, and the consequent production of a thin limpid spirit.

Coagulating substances are great clarifiers when mixed with any turbid liquor, the process of coagulation entangling with it all matters merely suspended and not dissolved, and carrying them either to the *top* in the form of a scum, or to the *bottom* in the form of a thick sediment, according to circumstances. Thus to clarify muddy cyder, the liquor is beaten up with a small quantity of fresh bullock's blood, and suffered to stand at rest for some hours, after which the liquor above is as clear as water, and almost as colourless, and at the bottom is a thick tough cake consisting of the coagulated blood which has carried down with it all the opaque matter suspended in the liquor. Many other albuminous and gelatinous substances act in the same manner. The effect of white of egg in this way is known to every one. It should be first mixed with the turbid liquor (a syrup for example) without heat and by agitation. Afterwards on applying less than a boiling heat the albumen of the egg coagulates, and carries up with it all the opaque particles of the syrup, leaving the rest beautifully clear and limpid.

Sometimes clarification takes place in a very unaccountable manner. Thus it is well known that a handful of marl or clay will clarify a large cistern of muddy water, and marl is also used with advantage in clarifying vinous liquors.^c

Mere heat will often clarify. Thus the expressed juice of cabbage plants is a strong-smelling, green, clammy, muddy liquid. By heating, all the turbid matter separates in the form of a green coagulum, and the liquor that remains is almost as limpid as water.

Clarification may often be detrimental. In many liquid medicines, such as decoctions of medicinal vegetables and the like, the medicinal portion resides chiefly in that part which is merely suspended, and therefore when separated by any kind of coagulation, the clear liquor is left nearly inert. See *Filtration*.

CLAY. *Thon*; Germ. *Argille*, Fr.

Any natural earthy mixture which possesses plasticity and ductility, when kneaded up with water, is in common language called a *clay*, which term is probably derived from the Latin *glarea* through the medium of the French *glaise*. All mineralogists however have comprehended within the appellation not only clays properly so called, but a few other mineral substances

^a Dizé.

^c Parmentier An. Chim. tom. 39.

nearly allied to some of the clays, and which become plastic by decomposition. Clay however is by no means a mineral species strictly speaking, being in most cases, perhaps in all, the result of the decomposition of other minerals. It seems advisable therefore to consider the property of plasticity as an essential character, and to exclude from the class of clays all earthy bodies that are destitute of it.

Mineralogists have hitherto arranged all the plastic clays under two species, rather from the economical uses to which they are applied than according to their external characters, composition or geological situation: the first species is the white infusible *porcelain clay*, and the second contains all the rest confounded together, under the general appellation *Potters' clay*. That this mode of arrangement is very defective will be readily allowed, and the reader it is hoped will receive with candour the following attempt at a more scientific classification.

Essential character. *Plastic by intimate mixture with water.*

1. *Porcelain clay.*

Its colour is generally reddish-white, also greyish and yellowish-white: it has no lustre nor transparency. It occurs either friable or compact; stains the fingers; adheres to the tongue; is soft but meagre to the feel: is easily broken. Sp. gr. about 2.3. It falls to pieces in water, and by kneading becomes ductile, though not in a very great degree. The Cornish porcelain clay certainly originates from the decomposition of felspar, and contains particles of quartz, mica, and talc, from which it is separated by elutriation. The Chinese kaolin also contains mica, and is probably of the same origin as the Cornish. The same remark may be applied to the French, &c. It is however by no means certain that all porcelain clay is derived from felspar, as it varies considerably in its composition and fusibility; all the kinds indeed are infusible at any temperature less than a white heat, but some, especially the Japanese, are refractory in the most powerful furnaces. The Cornish clay, according to Wedgewood, consists of 60 per cent. alumine, and 40 flint. That from Limoges in France, according to Hassensfratz, contains 62 flint, 19 alumine, 12 magnesia, 7 sulphate of barytes. Another specimen of the same, analysed by Vauquelin, gave 55 flint, 27 alumine, 2 lime, 0.5 iron, 14 water. A porcelain clay analysed by Rose, gave 52 flint, 47 alumine, 0.33 iron.

2. *Steatitic clay.*

Its colour is a light flesh red passing into

cream colour; its texture is minutely foliated; it has a slight somewhat greasy lustre and takes a polish from the nail. It stains the fingers, is very friable, and has a smooth unctuous feel. When laid on the tongue it dissolves into a smooth pulp without any gritty particles; it is very plastic and has a strong argillaceous odour. It occurs in nodules, in a hard cellular hornstone that forms large mountainous masses near Conway in North Wales, and originates from the decomposition of indurated steatite.

3. *Clay from Slate.*

Its colour is ash-grey passing into ochre-yellow: its texture is foliated: it has a smooth unctuous feel, and its siliceous particles are so small as to occasion scarcely any grittiness between the teeth. It occurs in thin beds on the tops of the softer kinds of slate-rock, and from its imperviousness to water is always found lining the bottoms of the peat mosses with which this kind of mountains is generally covered, and in these situations it is of a white ash colour, being deprived of its iron and carbon by the acid of the peat. It also occurs in thicker beds at the foot of the mountains, but is of a darker colour and less plastic.

4. *Clay from Shale.*

Its colour varies from greyish-blue to bluish black: its texture is foliated: it has a smooth unctuous feel, takes a polish from the nail, is excessively tenacious and ductile, and has but a slight degree of grittiness. When burnt it acquires more or less of an ochre-red colour: those varieties which are of the deepest red usually contain before burning a portion of sulphuric acid. It is for the most part difficult of fusion. It occurs abundantly in all collieries, and is produced by the spontaneous decomposition of the shale with which the beds of coal are covered. A sandy clay of a greyer colour and more refractory nature is procured from the decomposition of the indurated clay that forms the floor of the coal, and is provincially called *clunch*. The Sturbridge clay from which crucibles, glasshouse-pots, &c. are made, is of this kind.

5. *Clay from Trap.*

At the foot of the softer rocks of trap-formation, such as wakke, clay-porphry, and some varieties of grunstein and hornblende rock, are found beds of clay evidently originating from the gradual disintegration of these by the weather. The colour of this clay is generally brownish grey verging to ochre yellow; it occurs in mass, is of a compact texture, unctuous, tenacious, gritty and probably is not very infusible.

6. *Marly clay.*

The colour of this is bluish or brownish red: it occurs either compact or foliated: it has a soft unctuous feel, takes a polish by friction with the nail, is very plastic, more or less gritty, though not so much so as the common alluvial clay. It burns to a brick of a buff or deep cream colour, and at a high heat readily enters into fusion. It effervesces strongly with acids, and contains from $\frac{1}{4}$ to $\frac{1}{10}$ of carbonated lime. It originates sometimes from the decomposition of compact argillaceous limestone, but more frequently from the softer slaty varieties usually called stone marl. It is largely employed as a manure, and where the calcareous part does not exceed 10 or 12 per cent. it is esteemed as a material for bricks.

7. *Clay from metallic veins.*

Its colour is grey verging into bluish, greenish and yellowish, or red. It has a smooth unctuous feel, is very tenacious, often contains sulphuric acid and certain metallic oxyds which are never observed in other clays, such as lead, silver, antimony, copper, and bismuth. Is found in metallic veins.

8. *Alluvial clay.*

The circumstances which characterize alluvial clay are the following. It contains a larger proportion of quartz sand than the preceding, rounded pebbles of various kinds are also imbedded in it; thus showing it to have been carried from its native situation and mingled in its progress with a variety of extraneous bodies. At least three kinds of it may be distinguished, viz. Pipe clay, Potter's clay, and Chalky clay.

Pipe clay is of a greyish or yellowish white colour, an earthy fracture and a smooth greasy feel: it adheres pretty strongly to the tongue, is very plastic and tenacious; when burnt is of a milk-white colour; is difficultly fusible, though much more so than porcelain clay, from which it is further distinguished by its superior plasticity and the sand which it contains. It is manufactured into tobacco-pipes, and is the basis of the white or Queen's-ware pottery.

Potters' clay is of a reddish, bluish or greenish colour, has a somewhat fine earthy fracture, and a soft, often greasy, feel: it adheres to the tongue and is very plastic. It burns to a hard porous red brick, and in a higher heat runs into a dark-coloured slag. When tempered with water and mixed with sand it is manufactured into bricks: those varieties that are the most free from pebbles are made into tiles and coarse red pottery.

Chalky clay is of a leaden blue colour, an earthy fracture and a meagre feel: it is plastic, but breaks down by exposure to the weather. It contains a large proportion of sand and rounded pieces of chalk of all sizes up to that of a hazle nut. It effervesces strongly with acids, burns to a red porous brick, and is very fusible. It is used as a manure in the counties of Lincolnshire, Norfolk, and Suffolk.

CLAY pure. See ARGIL native.

CLAY slaty. See SHALE.

CLAYSTONE. *Thonstein*, Werner.

Its colour is greenish, bluish, or ash-grey, or brownish-red; it is sometimes marked by brownish yellow spots and stripes. It occurs in mass. Its fracture is fine grained earthy passing into even, slaty or splintery: some varieties are flat conchoidal. It is opaque, dull, frangible and soft; has a meagre feel and does not adhere to the tongue.

It forms large mountainous masses, occurring in beds, veins, and as the basis of clay porphyry. It passes into shale and jasper, and decomposes into clay.

CLYSSUS OF NITRE. The term *clyssus* used by the old writers in chemistry and alchemy is defined to be* the vapours that arise from the detonation of nitre with any inflammable substance; the *clyssus of nitre*, the vapours from nitre and charcoal (for which see *Nitrous Acid*), the *clyssus of sulphur*, the vapours from sulphur and nitre, &c. The term is now obsolete, but modern chemistry still derives great advantage, in many cases, from this mode of decomposition by nitre.

COAGULATION. *Gerinnen*, G.

Coagulation is the solidification of a liquid produced without evaporation, and without its assuming a crystalline form. The sudden hardening of the white of egg by mere heat is a familiar example of the kind. The term is sometimes applied also to a very sudden and confused crystallization, in which the crystallized particles appear amorphous to the naked eye, though when examined with a glass they exhibit some regularity of form. Thus, when strong sulphuric acid is added to a very concentrated solution of potash, the whole coagulates immediately to a nearly solid mass of granular crystals of sulphat of potash.

COAK. Pit coal deprived of its volatile ingredients by charring in the open air or in an oven, is converted to a light porous spongy mass called coak or cinders. For further particulars see COAL.

* Macquer. Chem. Dict.

COAL. ^a *Kohle*, Germ. *Houille*, Fr.

Mineralogists are by no means agreed in their arrangement of this important genus of mineral inflammables, we shall therefore with the less scruple differ in some degree from them all. It appears to be upon the whole the most convenient as well as more conformable to nature to include both the carbonaceous and carbonobituminous fossils under a single genus, subdividing it into the families of Brown Coal, Black Coal, and Mineral Carbon.

* *Brown Coal*. Imperfectly bituminous; of a brown colour, and vegetable texture.

Sp. I. Bituminized wood. *Ligniform carbonated wood*, Kirw. *Bituminöses Holz*, Werner. *Bois bitumineux commun*, Broch. *Surturbrand*, Iceland.

Its colour is brown approaching to brownish-black. Its external shape exactly resembles that of compressed trunks and branches of trees; its internal texture is precisely that of wood, retaining not unfrequently even the bark. Its fracture in the small is fibrous, in the great, flaty. The principal fracture is glimmering and lighter coloured than the cross fracture, which is shining, and sometimes imperfectly conchoidal. Its fragments are splintery, wedge-shaped. It is opaque, soft, gives a shining streak, is somewhat elastic and flexible, and almost light enough to float on water. It burns with a clear flame though with but little heat, and gives out a bituminous odour often mixed with that of sulphur.

The Surturbrand of Iceland, according to Bergman, contains 58 per cent. of watery and volatile inflammable matter, the carbonaceous and earthy residue amounting to 42 per cent. In the bituminized wood of Rollo, Vauquelin found

54. vegetable earth,
10.7 sulphat of iron,
0.8 sulphur,
12.7 oxyd of iron,
0.7 sulphat of lime,
0.2 filix.

79.1
20.9 loss.

100.0

Bituminized wood occurs usually in alluvial land among the beds of common brown coal; sometimes also forming beds by itself: in the Prussian amber mines it forms the stratum immediately above the amber, and nodules and

stalactites of this beautiful substance are generally found intermixed. It is also met with in dispersed fragments in alluvial clay. It abounds also in the newest floetz-trapformation, and forms masses in limestone and sandstone belonging to the independent coal-formation.

It is found in Britain at Bovey, near Exeter, in the isles of Skye and Cannay, in the coal strata of Mid-Lothian; in Bohemia and various parts of Germany; in France, Iceland, and Russia.

It passes into common brown coal and pitch coal, and is occasionally penetrated by quartz. It is employed as a fuel, but is greatly inferior to black coal.

Sp. II. Earthy Brown-coal. *Scaly and earthy carbonated wood*, Kirw. *Erdkohle* of Werner. *Bois bitumineux terreux*, Broch.

Its colour is blackish or wood-brown or yellowish-grey: it occurs in masses, of a consistence between solid and friable. It is without lustre except when rubbed or cut, and then it becomes somewhat shining. It soils the fingers a little: its fracture is intermediate between uneven and fine earthy. It is very soft and falls easily to pieces. Sp. gr. a little greater than that of water.

It readily takes fire and burns with a weak flame and disagreeable bituminous odour. Alcohol when digested with it takes up a brownish bitter substance, analogous to vegetable extract: by distillation it yields a yellow empyreumatic oil, soluble in alcohol, and which when deprived of its moisture by a gentle heat, acquires the consistence of butter or cerate.

It contains from 15 to 20 per cent. of earth and oxyd of iron, the remainder being water and inflammable matter. It often contains pyrites, and then passes into the earthy ore of alum, *alaunerde*, which see.

It is found in similar situations with the preceding species: in the neighbourhood of Leipzig it occurs in beds from 20 to 40 feet thick, and of great extent.

It is used as an inferior kind of fuel, especially in manufactories where a low degree of heat is required; for this purpose it is moistened with water, well beaten and made into brick-shaped masses. In the vicinity of Cologne a variety is found of a rich reddish-brown colour, which is prepared as a pigment under the name of Cologne umber.

Sp. III. Common Brown-coal. *Compact carbonated wood*, Kirw. *Gemeine braunkohl*, Werner. *Houille brune*, Broch. *Bovey coal*.

Its colour is light brownish black passing into

* Brochant, Kirwan, Jameson, Haüy.

blackish brown. It occurs in mafs: its parallel fracture is fibrous lamellar, passing into flaty, and is slightly glimmering; its cross fracture is more or less conchoidal with a shining resinous lustre. It acquires a polish by friction; is moderately hard. Sp. gr. 1.4 to 1.55; the heaviest varieties contain pyrites.

It burns readily with a weak flame like half-charred wood and a disagreeable bituminous odour, and when heated in close vessels it yields much charcoal; when ignited in an open fire it leaves behind a small quantity of white ashes. 200 grains, according to Hatchett,^b yield by distillation

60	grains acidulous water,
21	thick brown oily bitumen,
90	charcoal,
29	hydrogen, carburetted hydrogen, and
—	carbonic acid.
200	

In England it is found at Bovey near Exeter, and is called Bovey coal: at this place there are seventeen strata within the depth of seventy-four feet from the surface, alternating with alluvial clay: the greatest thickness of the seams is between six and eight feet. Brown coal is also found in the territory of Hesse, and various other parts of Germany, in Denmark and Greenland, and in Italy.

It is used like the preceding species, for fuel. It passes into bituminous wood and moor-coal, sometimes into pitch-coal.

Sp. IV. Moor coal. *Moorkohle*, Werner. *Houille limoneuse*, Broch.

Its colour is dark blackish brown. It occurs in mafs forming very thick beds, and is characterized by being always full of rifts and crevices. Internally it displays a considerably resinous lustre. Its longitudinal fracture is imperfectly flaty, its cross fracture is even, approaching to flat conchoidal. Its fragments are trapezoidal or rhomboidal. It is tender, remarkably frangible, and light. In its chemical characters it resembles the preceding species.

It occurs in alluvial land and in the newest floetz-trap-formation. It is met with very frequently in Bohemia, and is also found in Transylvania and other parts of the Austrian dominions, in Denmark and the Faroe islands.

** *Black Coal*. Perfectly bituminous; of a black colour.

Sp. V. Slate coal. *Schiefer Kohle*, Werner. *Houille schisteuse*, Broch.

Its colour is perfect black passing into greyish-black, and often presents more or less of an iridescent tarnish. It occurs in mafs and generally possesses a high resinous lustre. Its principal fracture is strait flaty, the cross fracture is small-grained uneven, passing into flat conchoidal. It breaks into indeterminately angular or trapezoidal fragments. It is soft and easily frangible. Sp. gr. 1.25 to 1.4. It contains from 57 to 64 per cent. of carbon, from 33 to 43 of bitumen, being a mixture of maltha and asphalt, and from 3 to 6 per cent. of earth and oxyd of iron. It runs into the two following varieties.

Var. 1. Foliated coal. *Blatterkohle*, Werner. *Charbon lamelleux*, Broch.

This differs from the preceding in having a somewhat higher lustre, and a strait foliated longitudinal, and flaty cross fracture. It is also softer and more subject to decomposition.

Var. 2. Coarse coal. *Grobkohle*, Werner. *Houille grossiere*, Broch.

The cross fracture of this displays a coarser granular texture than common slate-coal; its colour is not so pure a black, it possesses less lustre, is considerably harder, and its sp. gr. on account of the greater quantity of earth that it contains, amounts to about 1.5.

Most of the common coals belong to this species, and from the different phenomena which they exhibit during combustion, a great number of varieties are known in the market, and are sufficiently obvious to an experienced eye, which yet cannot be described.

The two points which are principally to be attended to with regard to common coals, in an economical point of view, are the intensity of the heat and the duration of the combustion, and these are chiefly influenced by the proportion of asphalt which they contain. Coals in which the bituminous part is chiefly maltha, with only a small quantity of asphalt, kindle very easily, burn briskly and quickly with a bright blaze, cake but little, require no stirring, and by a single combustion are reduced to loose ashes, such are the Lancashire coals, the Scotch, and most of those which are raised on the western side of England. Those on the other hand in which asphalt prevails kindle difficultly, and after lying some time on the fire become soft and in a state of almost semifusion; they then cohere or cake, swell considerably, and throw out on every side tubercular scoriæ accompanied by bright jets of flame. In consequence of the cohesion and tumefaction of the coals, the passage of the air is interrupted, the fire burns,

^b Phil. Transf. for 1804.

hollow and would be extinguished if the top were not broken in from time to time. The produce of ashes is smaller than in the free burning coals, the greater part of them being mixed with the carbonaceous part of the coal and forming grey scoriæ, commonly known by the name of cinders, which being burnt again with fresh fuel give out an intense heat, and are slowly reduced, partly to heavy ashes and partly to slag. The best coal of Northumberland Durham and Yorkshire is of this kind: it burns longer and gives more heat than the preceding, and in general bears a higher price.

Slate coal is found principally in the independent coal-formation, and is the most widely diffused of any of the species. It is often mixed with pyrites, and penetrated by thin veins of quartz or calcareous spar.

Sp. VI. Pitch coal. *Pechkoble*, Werner. *Houille piciforme*, Broch.

Its colour is velvet black passing sometimes into brownish black. It occurs in masses, in plates, and sometimes in the shape of branches with a regular woody structure. It has a brilliant resinous lustre, and a perfectly conchoidal fracture; the surfaces of the natural joints are nearly specular: its fragments are indeterminate sharp-edged. It is soft and brittle. Sp. gr. 1.3.

It burns with a greenish flame and a strong bituminous smell, and leaves behind a light yellowish coloured ash. It occurs principally in the newest floetz-trap coal-formation. It is used as fuel, but the finer and harder pieces are worked into various trinkets, and go under the name of jet. It occurs in detached fragments in the Prussian amber mines, and is there called black amber.

Sp. VII. Cannel coal. *Kennelkoble*, Werner. *Houille de Kilkenny*, Broch. (This mineralogist however is entirely in an error in supposing cannel and Kilkenny coal to be the same, the latter of these being a variety of Glance coal. See species 8.)

Its colour is dark greyish black. It occurs in masses: has a glistening resinous lustre. Its longitudinal fracture is flat conchoidal, its cross fracture is perfectly conchoidal. When cut with a knife it exhibits a shining lustre, and the cut surface is full of very minute conchoidal fractures, giving it a porous appearance. It is brittle, but is the most difficultly frangible of all the coals. Sp. g. 1.23. It is very inflammable, and crackles and flies while burning, especially if it is not laid in the direction of the cross fracture: it flames much and burns quickly, but does not cake, and leaves behind from 3 to 4 per cent of ashes.

The splent coal of Scotland is an inferior variety of cannel: its principal fracture is slaty, its cross fracture imperfectly conchoidal; its sp. gr. 1.42. It contains pyrites, and leaves about 21 per cent. of ashes.

Cannel coal occurs in the independent coal-formation. It is found in great plenty and remarkably pure at Wigan in Lancashire, and occasionally in most of the other English collieries.

The splent coal abounds at Gilmerton, near Edinburgh.

Its chief use is as a fuel, but the purest Wigan cannel will bear to be worked in the turning lathe, from which it receives a high polish: hence it is shaped into various ornamental utensils, and when cut into beads is not to be distinguished from jet.

*** *Mineral Carbon*. Destitute of bitumen; consists of charcoal, with various proportions of earth and iron.

Sp. VII. Mineral charcoal. *Mineralische Holzkoble*. Werner.

Its colour is greyish black. It occurs in plates and irregular pieces. It has a glimmering silky lustre, and a fibrous fracture discovering its ligneous texture. It soils the fingers, is soft and friable. It is somewhat heavier than common charcoal, and is easily reduced to ashes before the blowpipe without flaming.

It occurs in thin layers in brown coal, slate coal, slaty glance coal, and pitch coal, but in too small quantities to be made any separate use of.

Sp. VIII.. Glance coal.

Of this there are three varieties.

Var. 1. Conchoidal glance coal. *Muschliche glanzkoble*, Werner. *Houille eclatante*, Broch.

Its colour is iron-black, inclining to brown. It occurs in masses and vesicular, the interior of the vesicles has a steel blue tarnish. It has a bright shining metallic lustre, and a perfectly conchoidal fracture. Its fragments are indeterminate angular, and sharp-edged. It is moderately hard, frangible and light.

It burns without flame or smell, and leaves a white ash. That from Hesse has been analyzed, and contains

96.66 charcoal
2. alumine
1.33 oxyd of iron

99.99

It is of rare occurrence, having been met with only in the Meissner in Hesse, and at Newcastle.

Var. 2. Columnar glance coal. *Stangenkoble*, Werner. *Houille scapiforme*, Broch.

Its colour is dark greyish black, sometimes verging to brownish black, the sides of its natural divisions are often covered with a yellow ferruginous earth. It occurs in mafs. It poffeffes a fhining luftre, between refinous and metallic. Its fracture is more or lefs perfectly conchoidal. It always occurs in thick, curved, parallel, columnar, diftinct concretions, having fmoother glimmering fufaces. It is foft, very eafily frangible and light.

It burns without flame or fmell, and leaves a greyifh white afh. It has hitherto been only found at the Meiffner in Hefle, where it occurs together with other coal in the neweft floetz-trap-formation.

Var. 3. Slaty glance coal. *Schiefrige glanzkoble*, Werner. *Kohlenblende* of Broch. Emmerl. and Wiedenm. *Anthracite*, Haüy and Dolomieu. *Kilkenny coal*. *Welsh culm*.

Its colour is dark iron black, verging on fteel-grey. It occurs in mafs: has a bright metallic luftre: its principal fracture is more or lefs curved flaty, its crofs fracture is fmall and imperfectly conchoidal. It breaks eafily into indeterminate angular fragments. Sp. gr. 1.5 to 1.8.

When pulverized and heated on a muffle it becomes red, and fowly confumes, with a very light lambent flame, without fmoak; it does not cake, and when pure emits no fulphureous or bituminous odour: it leaves a variable proportion of reddifh afhes, and the unconfumed particles retain their original colour and luftre.

The Kilkenny coal is fomewhat harder than is customary with this variety, it poffeffes a very brilliant luftre, which by long keeping is impaired, in confequence of a light olive tint which overfpreads it from decomposing pyrites. Some kinds being nearly pure burn without any fmell, but it often gives out a ftrong fulphureous odour. Thofe fpecimens that abound in pyrites alfo contain mineral charcoal.

Slaty glance coal confifts of carbon, with from 3 to 30 per cent. of earth and iron: the following are the principal analyfes which have been made of this fubftance.

	Vauquelin	Dolomieu	Panzenberg
Carbon - -	68	72.05	90 90
Silex - -	30	13.19	2 4
Alumine - -	—	3.29	5 4
Oxyd of iron	2	3.47	3 2
	100	92.00	100 100

This mineral occurs in imbedded mafles, beds and veins in primitive, tranfition, and floetz rocks. It is found in gneifs, in micaceous and argillaceous fchiftus, in mineral veins, with calcareous fpar, native filver, mineral pitch, and red iron ore, and has been difcovered by Jamefon in the independent coal-formation in the Ifle of Arran.

Sp. IX. Plumbago. *Graphit*, Werner. *Graphite*, Broch. *Fer carburé*, Haüy. *Black-lead*.

Its colour is dark iron black, paffing into fteel-grey. It occurs in mafs, in kidney-fhaped lumps, and diffeminated. It has a gliftening metallic luftre: its fracture is fmall fomewhat curved foliated approaching to fcaly, or granular uneven; in the great it is flaty. It occurs generally in granular or fcaly diftinct concretions: it takes a polifh by cutting or rubbing, gives a dark lead-grey ftreak, is unctuous to the feel, foft, and not very brittle. Sp. gr. 1.98 to 2.26.

When heated it does not flame, nor can it fupport combuftion by itfelf. After long exposure to a high heat on a muffle its carbon is burnt off, and its earthy and metallic part remains behind.

The purer kind of plumbago, according to Scheele and Berthollet, confifts of about 90 per cent. of carbon and 10 of iron. An impure kind from Pluffier afforded Vauquelin

23 carbon
2 iron
37 alumine
38 Silex

100

It is found in primitive and tranfition rocks in England, Scotland, France, Spain, Germany, &c.

Its moft important ufe is as a material for pencils to write or draw with, for which purpofe none that has yet been difcovered is comparable to that from Borrowdale in Cumberland: it is fometimes ufed to lubricate machinery with inftead of oil; alfo to protect iron from ruft, and, when mixed with clay, as a material for crucibles.

Modern mineralogifts diftinguifh three different kinds of coal-formation, or three feries of rocks entirely different from each other, which contain coal; and as a knowledge of thefe is important both in an economical point of view, and to enable us to form a juft theory concerning the origin of this interefting mineral,

we shall give a short account of the principal facts that are ascertained on this subject.

The independent or true coal-formation consists essentially of extensive parallel strata of coal, covered by strata of shale, which contain impressions of vegetables, and sometimes the remains of fresh-water shell-fish. Beneath each stratum of coal is generally a stratum of somewhat greasy indurated clay, called by the miners *clunch*, which is usually, if not always, destitute of those organic remains that characterize the shale. It rarely happens that the slate belonging to an inferior stratum of coal is in immediate contact with the clunch of a superior stratum, the coal seams being generally separated from each other by beds of various coloured sandstone, of clay, of bituminous shale, of ratchil or rubble-stone, of a soft decomposing clay porphyry, or grüstein, called by the English miners rotten-stone, of argillaceous iron ore, of marl, and of secondary limestone. Sometimes one, often several of these strata interpose between the seams of coal in irregular alternation, and there are extensive collieries in which some of them, especially the limestone, are entirely wanting. The number of seams of coal in any particular formation or coal-field is extremely variable; it seldom however happens that there are more than three or four worth the expence of working. The uppermost seam is generally shattery, and very much mixed with earth and pyrites. The parallelism of the various strata is for the most part very exactly preserved, though where a very thick bed of sandstone occurs, the strata above and below it have not always the same parallel. The general position of the beds in the independent coal-formation is scarcely ever horizontal, and never vertical, though occasionally forming an angle of about 75° . The regularity of the dip, however, is frequently interrupted by partial disruptions, slips, and sinkings of the strata, emphatically called by the miners *troubles*, which appear like great cracks and are filled with sand, gravel, clay, &c. and afford a free passage for the water. Sometimes the strata are divided by vertical walls of basalt, rising from an unknown depth to the surface, and of vast length; these are called by the miners *dykes*, and differ from the slips in being impermeable to water, and in simply dividing the strata without altering their direction: both the slips and the dykes however are observed to shatter and pulverize, and decompose the coal in their immediate vicinity. The particular species that are found in the independent formation are slate coal, with

its varieties, cannel coal, and sometimes pitch-coal. Almost all the English coals, and those in the neighbourhood of Liege, are found in this formation.

The second coal formation is characterized by the newest floetz-trap. In this the strata are not so numerous nor so perfectly parallel as in the former. The coal is not covered with shale, but with clay or basalt, in which are found neither vegetable impressions nor animal remains. The beds which compose this formation are wakke, basalt, both amorphous and columnar, grüstein porphyry, and argillaceous iron ore. Slips or disruptions of the strata are not common in this formation, but dykes are of frequent occurrence. The species of coal which it contains are principally pitch-coal, also moor and glance coal, and sometimes slate-coal. The chief collieries of Scotland, those of Auvergne and the central parts of France, of the Meißner in Hesse, and the Mittelgebirge in Bohemia are examples of this formation.

The third coal-formation occurs in alluvial land, and possesses many characters that distinguish it from the preceding ones. The only strata which are found in it, are clay, sand, and gravel. The seams of coal do not preserve the same thickness through the whole of their extent, nor is the parallelism of the earthy strata by any means regular, sudden elevations and depressions in the same stratum, frequently taking place. There are no slips or dykes in this formation, and every appearance concurs to prove its very recent origin. The species of coal that it contains belong chiefly to the brown-coal family, namely bituminized wood, earthy and common brown-coal, moor-coal, and rarely pitch-coal.

The signs of coal are very uncertain both in the floetz-trap and alluvial formations. In the first of these no appearance is to be depended on except the actual outburst of coal, or of a bed of clay, containing fragments of coal. In the second, the only probable indication is clay, with branches and trunks of trees: petrified wood is often found in considerable quantity in sandstone strata, without there being the slightest probability of a bed of coal beneath.

The independent coal-formation has however more numerous signs, and those better to be depended on. Being the oldest of the three formations it is situated nearer the primitive and transition rocks than the others, and in general appears to rank immediately after secondary limestone: where beds of this adjoin, and rest upon slate, as is frequently the case in the

northern and western parts of England, the independent coal-formation is generally observed within a little distance of the limestone on the opposite side to the slate-rock, and therefore divided from it by the limestone. The extensive collieries of Flint, Ruabon and Chirk in North Wales, of Glamorganshire in South Wales, of Coalbrook-dale in Shropshire, and Kingswood, near Bristol, are all examples of this, all of them commencing immediately in the vicinity of secondary limestone, which itself on the opposite side may be traced into slate: in some of these instances the limestone does not exceed a few hundred yards in width, while in others it amounts to several miles. Among the strata of which the coal-formation itself is composed, limestone, clay, and marl, are the least certain indications, as these are met with most frequently in formations unconnected with coal. White micaceous sandstone, especially when in thin layers is a promising sign: argillaceous iron is still more so; but shale with vegetable impressions, or the tenacious blue clay into which it decomposes, is the strongest indication of all: there are few situations in which this shale or clay occurs where an accurate search will not discover detached fragments of coal, and often the crop or outburst of the seam itself; and even should these be wanting, it will be well worth while to employ the borer and pierce through the shale, immediately beneath which a seam will be found, if it belongs to the coal-formation.

From the vegetable remains with which the shale that lies upon coal is always filled, from the ligneous texture which may be traced here and there, even in the most compact species of coal, and from the regular and gradual transition of bituminized wood through pitch coal, and slate coal, into glance coal, it is now generally supposed that all coal (plumbago excepted) is of vegetable origin. As to the precise mode and agent by which the process of bituminization has been brought about, the manner in which, and the period when the successive strata of the coal-formations have been deposited, there exists and probably ever will exist, various theories more or less ingenious and consistent, which although in all likelihood very remote from the truth are valuable as exciting to further enquiry, and as convenient methods of arranging and collecting many very curious and important facts. To enter into the detail of these, however, would be deviating too far from the practical objects of the present work.

The great use of coal is as a material for

fuel, and it is used either in its crude state, or after it has been converted into coak by a process analogous to that by which wood is made into charcoal.

Unprepared coal is employed in all manufactures in which liquids are to be boiled or evaporated, such as brewing, salt-making, distilling, and dying; it is used also in this state by glassmakers, blacksmiths, and limeburners, and in all metallurgical processes in the large way, where fusion is performed in a reverberating furnace. As a domestic fuel also it is used for the most part without any preparation; but in some places where coal cannot readily be procured, it is reduced by pounding, to the consistence of small gravel, and worked up with an equal weight of tenacious clay, and moulded into balls of the size of the fist. These being first well dried in the air are made use of as fuel, and are found to burn longer and give out more heat than the coal would do without this addition. The only inconvenience attending these balls is, that they do not readily inflame, and therefore it is necessary at the kindling the fire to employ common coal, and not to add the balls till a sufficient body of fire has been collected.

In blast furnaces, and the upright smelting furnaces for iron and copper, coal cannot be used in its crude state, both because its sulphureous vapours would injure the quality and diminish the quantity of metal, and because by its caking the current of air would be obstructed, and the whole process thrown into disorder: neither can this combustible be employed, except in the state of coak, for drying malt and other similar processes in which smoaky fuel would be extremely prejudicial. Coal is deprived of its bitumen and other volatile parts, or in other words is made into coak, in various ways. The simplest mode is to dispose it in beds, from 40 to 60 yards long about six feet wide and three feet high, in the open air, and kindling it in various parts, to allow the combustion to proceed till the mass is of a glowing red and ceases to smoke: being now taken to pieces and spread abroad the fire soon goes out, and the residue is found to be a light spongy scoriform substance (technically called coak or cinders) not so easily inflammable as coal, but when once kindled giving out an intense heat without either caking or smoaking. The above is apparently a very wasteful process, not only because the volatile matters are allowed to escape, but by this free exposure to the air a considerable portion of the carbonaceous part is also lost: it has however

this advantage, that the sulphur is at the same time entirely got rid of, which cannot be done by close distillation, and in consequence the fuel is much better fitted for those purposes in which the presence of sulphur would be detrimental: for this reason doubtless it is that all the coak consumed in the numerous iron forges of this country is thus prepared. Another method of charring coal is to burn it in large vaulted ovens till it ceases to flame: this is more economical than the former, both because the product of coak is greater, and because the slack or small coal of the caking kinds may be employed for this purpose; all the volatile parts however are lost, and the coak is not entirely desulphurated.

In the county of Saarbruck on the Rhine, are some establishments for making coak and lamp-black at the same time, which perhaps might be found worthy of imitation in this country. The furnace^c is a long cylinder of brick-work placed somewhat in a slanting direction, terminated at the lower-end by a grate and register door, and opening at the other extremity into a large vaulted chamber: the first chamber communicates with a second similar to it, except that it is smaller, and this latter by means of an aperture in the ceiling opens into a chimney, a sack of loosely woven cloth being interposed. The process begins by lighting a fire in the furnace and supplying it gradually with coals, till the furnace is about half full, then by means of the register in the door, a small current of air is admitted till the coals cease to smoke; at this period the door is opened and the contents of the furnace are raked into a hole below its mouth, where they are extinguished, leaving however in the furnace a sufficient quantity of lighted coals to kindle the next charge. While the coals are thus charring the smoke passes into the large chamber, where it deposits the greatest part of its soot, and the rest is collected in the small chamber, and in the sack which covers the opening into the chimney. By a careful regulation of the draft it appears probable that the coal might be as completely desulphurated, and with as little loss as in the open air, and the lamp-black would be nearly a clear gain: 100 lbs. of coal thus treated afford about 33 lbs. of coak, and $3\frac{1}{2}$ of lamp-black.

Coal, when heated in close or nearly close vessels, affords a vast quantity of a highly inflammable gas (already described as a variety of CARBURETTED HYDROGEN) of Coal-Tar, or PETROLEUM, and of impure carbonated am-

monia. From a laudable desire of saving the two latter valuable products, which had hitherto been allowed to escape in the process of coaking, Lord Dundonald erected some years ago at Coalbrook-dale, and we believe elsewhere, a series of buildings to serve as a kind of distillatory apparatus, in which he prepared coak, and at the same time collected the petroleum and ammonia disengaged in the process: his success was complete, as far as the distillation was concerned, but the undertaking was shortly abandoned in consequence, as we understand, of the sulphur contained in coak thus made, which rendered it unfit to be used in the furnaces. Indeed it is manifest, that in order to decompose the pyrites with which all coal more or less abounds, it is necessary to expose it while burning to such a stream of air as shall destroy both the petroleum and ammonia, and leave no opportunity for the exertion of economical ingenuity, except in the collection of soot and increasing in some degree the product of coak.

COATING, or *Lorication*. See CEMENTS.

COBALT. *Cobalt*, Fr. *Kobalt*, Germ.

Cobalt when pure is a metal of a white colour inclining to bluish or steel-grey, when tarnished acquiring a reddish tinge: its fracture is compact, fine-grained uneven. At the common temperature it is brittle and pulverizable, but when red hot will bear to be in some degree extended under the hammer. Its specific gravity is ≈ 8.53 . It is attracted by the magnetic needle, and is itself capable of polarity. It requires for its fusion nearly the same intensity of heat as cast iron does. When in the state of oxyd it tinges the saline vitreous fluxes of a deep blue colour. It is soluble in nitromuriatic acid, and the diluted solution forms a blue sympathetic ink. It occurs, 1. mineralized by arsenic; 2. as an oxyd; 3. combined with arsenic acid; 4. combined with sulphuric acid.

Sp. I. Arsenical Cobalt: ^a

Cobalt is never found pure in the metallic state, but is always alloyed with arsenic, and often contains besides a variable portion of iron and sulphur, besides which it is occasionally mixed with nickel, bismuth and silver. The amorphous sub-species have none of them been subjected to an accurate analysis, but the crystallized has been examined both by Klaproth and Tassaert. The former chemist obtained from the bright white cobalt of Tunaberg. (3d sub-species).

^c Journ. des Mines. No. 55, p. 487.

^a Emmerling, Widenmann, Haüy, Kirwan, Brochant.

44 Cobalt
55.5 Arsenic
0.5 Sulphur

100.0

The latter procured from the same variety,

36.66 Cobalt
49. Arsenic
5.66 Iron
6.5 Sulphur

97.82

2.18 Loss

100.

Similar differences are observable between the analysis of this variety by other chemists, so that it may be considered as allowing of a considerable range both in the proportion and nature of its constituent parts, without materially affecting its crystallization. It appears however from Haüy, that when the crystals display a lamellar fracture they contain a notable proportion of sulphur and iron. Kirwan, Haüy and others, form two species of cobalt ore according to the preponderance of arsenic or pyrites in their composition. Brochant and the later German mineralogists on the other hand form three species. This latter arrangement appears the most useful and exact, but as there are in reality no certain specific characters, we shall consider the whole as one species with three subdivisions.

1. Sub-species. White Cobalt. *Weisser Speiskobolt. Cobalt blanc.* (Species 2d. of Kirw. and Haüy.)

The colour of this mineral when recently broken is tin-white, but its surface is generally yellowish, bluish, reddish, or greyish, or iridescent like steel that has been heated. It occurs in masses, disseminated, kidney-shaped, and rarely in minute quadrangular tables, or imperfect cubes and octahedrons. Their external lustre is slight, but internally is brilliant and metallic. Its fracture is fine-grained, uneven: when broken, it flies into sharp-edged irregular fragments. When in mass it contains fine-grained granular distinct concretions. It acquires a polish by friction, is brittle and hard. When exposed to the blow-pipe white cobalt melts with great facility, giving out at the same time a white vapour and strong arsenical odour, a white brittle bead of metal remaining behind

which communicates a blue colour to glass of borax.

It is found in Norway, at Tunaberg in Sweden, Annaberg in Saxony, also, though rarely, in Swabia and Stiria. In Saxony and Norway it is contained in beds of micaceous schistus accompanied by the red earthy cobalt, quartz, hornblende and pyrites.

2. Sub-species. Dull-grey Cobalt. *Grauer Speiskobolt. Cobalt gris* (Sp. 1. of Kirw. and Haüy.)

The colour of this mineral is a clear steel grey, but by exposure to the air it acquires an iridescent tarnish. It occurs in mass or disseminated, sometimes in kidney-shaped or clustered masses, and very rarely in specular laminae. Its external lustre is very feeble, but internally it exhibits a bright metallic lustre. Its fracture is compact, generally even, but sometimes passing into flat conchoidal; its grain is remarkably fine and close. Its fragments are sharp-edged, indeterminate. It is not so hard as the preceding, and is less brittle. Its specific gravity varies from 4.3 to 5.3 or even 5.5. It gives a bluish-grey metallic streak.

When exposed by itself to the blow-pipe it gives out an arsenical vapour and smell, but seldom fuses: when treated in the same way with borax it gives the flux a blue colour, and is reduced to a metallic globule.

A specimen of this from Cornwall was analyzed by Klaproth, who procured from it about 20 per cent. of cobalt, 24 of iron, and 33 of arsenic, the remainder consisting partly of bismuth and sulphur, together with earthy matter; some varieties have also been found to contain nickel and silver.

It is somewhat rarer than the following sub-species, but is found at Schneeberg, Freyberg, and other places in Saxony, at Joachimsthal in Bohemia, Wittichen in Swabia, and Schmölnitz in Hungary; also in Stiria, at Allemont in France, in Norway, and in Cornwall. It is generally accompanied by other cobaltic ores, by kupfernikel, native bismuth, and silver.

3. Sub-species. Bright white Cobalt. *Glanz Kobolt. Cobalt éclatant* (Sp. 2. of Kirw. and Haüy.)

The colour of this mineral is tin-white, but tarnishes to greyish, yellowish, or iridescent. It is found in mass, or disseminated or investing; or of particular shapes as clustered, reniform, globular, interlaced, in spangles; or crystallized in cubes or octahedrons. The crystals are of middling size or small, their surface is com-

monly smooth and brilliant, and marked with striae on the sides of the primitive cube.

The fracture of the crystals is lamellar, that of the other varieties is fine-grained uneven, or radiated. When in mass it presents granular, or testaceous, or lamellar distinct concretions. In hardness it is somewhat inferior to the preceding sub-species; when pulverized it is of a steel-grey colour. Sp. gr. 6.2 to 6.3. It is brittle and easily broken.

When exposed to the blow-pipe it burns with a faint white flame, disengaging arsenical vapours; it then becomes black, is attractable by the magnet, and is with the utmost difficulty reduced to a metallic globule. It often affords as much as 50 per cent. of reguline cobalt.

This is the commonest of all the ores of cobalt: it occurs for the most part in primitive mountains, together with the other species of cobalt ore, with vitreous, red, and native silver, with arsenical and cupreous pyrites, &c. It is met with in many parts of Germany, but especially in Saxony and Bohemia, at Tunaberg in Sweden, at Modun in Norway, in the Pyrenees, in Stiria, and in Cornwall.

Species II. Earthy Cobalt. Of this there are the four following varieties.

Var. 1. Friable black cobalt, *Schwarzer Kobolt mulm. Cobalt terreux noir friable.*

The colour of this is black, bluish, brownish or greyish black. It has no lustre, is of a loose earthy consistence, friable and meagre; it stains the fingers in a slight degree, and gives a brightish streak. It is soluble in muriatic acid, tinges borax blue, and very rarely betrays any sulphureous or arsenical ingredient when treated with the blow-pipe.

Var. 2. Indurated black Cobalt. *Verhærteter schwarzer Kobolt. Cobalt terreux noir endurci.*

In colour it resembles the former, except that it is sometimes of a dark greenish black. It occurs massive, disseminated, investing, kidney-shaped, clustered or in veins. It is dull, but takes a polish by friction. Its fracture is earthy and compact, passing into flat conchoidal. It possesses a moderate degree of hardness. Sp. gr. from 2. to 4. With nitric acid it gives a red solution, and a bluish green one with muriatic acid. It has not been accurately analyzed, but consists of oxyd of cobalt with a small variable proportion of arsenic and sulphur mixed with vitreous silver ore, oxyd of iron and clay.

This and the preceding variety are always found together, but the indurated is by much the most rare. It is found in Saxony, Thuringia, Swabia, and Tyrol.

VOL. I.

Var. 3. Yellow Cobalt. *Gelber Erdkobolt. Cobalt terreux jaune.*

Its colour is that of faded straw, passing into greyish-white and often streaked with brick-red. It is found in mass, disseminated, or investing. It is without lustre, has a fine-grained earthy fracture, gives an unctuous streak, is soft and friable.

It is infusible *per se*, gives a feeble arsenical odour, and communicates a deep blue tinge to borax: but when mixed with iron, as it often is, the colour is greenish.

This is one of the rarest of the ores of cobalt: it has hitherto been found only at Saalfeld in Thuringia, Alpirsbach in Wirtemberg, and Allemont in Dauphiné.

Var. 4. Brown Cobalt. *Brauner Erdkobolt. Cobalt terreux brun.*

Its colour is a clear liver-brown passing into grey, yellow, and black. It occurs in mass or disseminated; it is dull, but acquires a greasy lustre by friction. Its fracture is fine-grained earthy. It is easily broken, being almost friable. It has not been analyzed, but appears to be the connecting link between the second and third varieties. When thrown on burning coals it generally gives out an arsenical odour.

Sp. III. Red Cobalt. Of this there are two varieties.

Var. 1. Crystallized. *Koboltblute. Fleurs de Cobalt.*

The usual colour of this mineral is peach-blossom red, passing into cochineal and greyish-red; by exposure to the air it becomes paler and almost white. It is found very rarely in mass or disseminated, and still seldomer clustered or kidney-shaped: its most usual state is that of a thin crystalline covering, or minute druses of crystals. The forms which it generally affects are rectangular tables, or tetrahedral acicular prisms, or hexahedral prisms terminated by dihedral summits: these figures however are not often determinable on account of the minuteness of the crystals, and their tendency to form radiated and globular groups. The surface of the crystals is smooth and brilliant, and their fracture lamellar. The fracture of the other kinds is radiated passing into fibrous. It is translucent, and often when crystallized semitransparent.

Before the blow-pipe it gives a faint arsenical odour, and becomes of a dark grey colour, it is almost infusible by itself, and gives a beautiful blue tinge to borax.

Var. 2. Earthy. *Koboltbeschlag. Cobalt terreux rouge pulverulent.*

The colour of this is the same as that of the preceding variety. It occurs in a pulverulent or indurated state, disseminated through or investing other minerals, and occasionally in mass. It is dull, opaque, and has an uneven earthy fracture. In other respects it agrees with the preceding.

Sp. IV. Native Sulphat of Cobalt. *Natürlicher Kobaltvitriol. Sulfate de Cobalt natif.*

At Herrengrund, near Neusohl in Hungary, is found a saline substance in the form of translucent stalactites of a pale rose red colour: it was at first supposed to be sulphat of manganese, but from an analysis by Klaproth it appears to be a pure sulphat of cobalt.

Reduction of the Ores and Analysis.

Cobalt is never employed in the reguline state for any purpose of manufactory, the sole use of this valuable metal being to give various shades of blue colour to glass, porcelain, and other earthy mixtures, and when thus employed it must be in the state of oxyd. But the intensity of colour given by the oxyd in very small proportion is so great that it is found more convenient, after due calcination, to mix and dilute it with a quantity of vitrifiable earth, and in this state it is generally sold, that is, either simply mixed with earth, when it appears as a brown gritty powder called *Zaffre*, or else already melted with a portion of vitrifiable materials when it becomes a glass of a most intense blue colour, which, when properly ground and sifted, forms the *Smalt* of the shops.

The preparation of these two articles of commerce will be mentioned, after the analysis of the cobalt ores has been described.

Many of these ores are complicated and difficult to analyze. The natural metallic admixtures with cobalt hitherto discovered are the following:

1. Arsenic, generally in very large quantity, part of which is in the state of reguline arsenic, and as it appears, another part is in the state of arsenic acid, or at least is brought to this state in the process of analysis. This unites with part of the cobalt forming an arseniat of cobalt, which has often been mistaken for the pure oxyd. The entire separation of the two is attended with much difficulty.

2. Nickel is abundantly mixed with many of the cobaltic ores, and not easily separated, being soluble in the same menstrua.

3. Iron, in variable quantity, generally adheres to the natural cobalts, and is a hurtful ingredient, as it much alters and impairs the

beautiful blue colour for which alone cobalt is valued.

4. Manganese, which now and then is mixed with the cobalt ores, has a still worse effect than iron on the colouring power.

5. A little copper is contained in some of the ores of cobalt, but does not much injure their quality.

An imperfect analysis of the cobalt ores resembling that of Tunaberg, and consisting chiefly of arsenic and cobalt is made in the dry way, by mixing the ore with charcoal,^a or better with saw-dust, and roasting it to expel the *arsenic*, with the precautions described under that metal. The remaining oxyd, after thorough calcination, should be mixed with about four times its weight of an equal mixture of carbonate of potash and tartar (or with any other saline reducing flux), and heated intensely for about 15 minutes in a heat sufficient to melt cast iron. A button of reguline cobalt is found beneath the scoria, which last are always of an intense blue almost black, owing to the solution of part of the cobalt-oxyd. From 100 grains of the ore of Tunaberg Klaproth obtained in this way 44 grains of regulus of cobalt, but this would obviously be impure whenever the ore contained iron, or copper, or nickel, nor is it quite certain that every atom of the arsenic would be expelled.

The reducing flux employed by Beaumé is the following: mix one ounce of roasted ore of cobalt with three ounces of black flux and half an ounce of potash, cover it when in the crucible with about one ounce of salt, and heat at first slowly, afterwards very briskly for about a quarter of an hour.

For the mere purposes of analysis the following laboured and accurate analysis of the same by Tassaert is much preferable,^b the particulars of which may be given, as the whole is extremely instructive.

That the reader may better understand the process it may be premised, that when reguline arsenic is boiled with a *little* nitric acid it is dissolved and converted into white oxyd, all of which is deposited by mere evaporation to a small bulk of liquid: but when *much* nitric acid is used, the arsenic is more or less acidified, becomes thereby much more soluble in water, and then acting as an acid, it readily dissolves cobalt, iron, &c. forming arseniates of those metals, which are decomposable by the fixed alkalies. It may be also added, that oxyd of cobalt is soluble in ammonia, but oxyd of iron is not, and

^a Klaproth.

^b An. Chim. tom. 28.

that the nitrat of iron deposits much of its iron by mere exposure to air, but the nitrat of cobalt remains clear.

A. To estimate the quantity of arsenic separately M. Tassaert digested 100 parts of the cobalt ore with *dilute* nitric acid, and in some hours the whole was dissolved, but by cooling deposited a quantity of white crystalline grains. On evaporation more of them were deposited, and when all had thus separated they were collected and dried, and weighed 56 parts, all of which was sublimed by heat except 3 parts, probably a mixture of arsenic and cobalt. Hence the oxyd of arsenic from this ore may be reckoned at about 53 parts, indicating 49 per cent. of metallic arsenic in the ore.

B. Three hundred parts of the ore were then digested with four times as much nitric acid, which made a rose-coloured solution. By partial evaporation, adding water, and heating, a rose-white precipitate (*a*) fell down, leaving a rose-coloured solution. This solution boiled with an excess of potash gave an oxyd of cobalt at first rose-coloured, then passing to green, and when dried in a red heat, black. It weighed 85 parts.

C. The 85 parts of the last experiment were then examined for iron. When re-dissolved in nitro-muriatic acid, pure ammonia was added, which gave a black precipitate, which was all re-dissolved by an excess of the alkali except a small portion, which, again treated with nitro-muriatic acid and ammonia, was reduced to 4 parts, and appeared to be oxyd of iron.

D. The rose precipitate of experiment B. which proved to be a mixed arseniat of cobalt and iron, was decomposed by caustic potash in excess, and gave a precipitate weighing 100 parts when dried.

E. The 100 parts of the last experiment were redissolved in nitric acid, the solution evaporated partly and then diluted with water. A precipitate of oxyd of iron weighing 27 parts then separated, and a clear solution of cobalt was left.

F. The nitrat of cobalt of the last experiment was decomposed by ammonia, and the precipitate redissolved by an excess of the alkali, except 15 parts of insoluble oxyd of iron. The solution was added to the ammoniated cobalt of experiment C.

G. The insoluble precipitates of oxyd of iron of C, E, and F were then mixed and examined. They still gave a blue glass with borax, and therefore contained a certain portion of cobalt. Acetic acid was found a good method of sepa-

rating them. For this purpose they were redissolved in nitro-muriatic acid, precipitated by just sufficient ammonia, and the precipitate whilst still wet was put into acetic acid. This dissolved the whole at first, but on boiling and evaporating the solution nearly to dryness most of the iron separated, and by redissolving in water and evaporating nearly to dryness successively four times, nearly all the oxyd of iron was rendered insoluble, whilst the cobalt remained in the solution, and this acetited cobalt in proportion as it was freed from iron became more and more of a fine rose colour. This last was then supersaturated with ammonia, and the solution of ammoniated cobalt was added to the different portions of the same obtained in the former experiments. The whole was then boiled to expel the excess of ammonia, and by adding potash the whole of the pure oxyd was precipitated, which when well washed and dried, weighed 133 parts. This oxyd reduced in a crucible lined with charcoal, gave regulus of cobalt in its purest form, of the specific gravity of 8.538, and to all appearance totally free from arsenic and iron.

H. Lastly, to estimate the quantity of sulphur, 100 parts of the ore were separately boiled with 500 of nitric acid, and diluted with water to separate all the oxyd of arsenic that would be deposited spontaneously. All the sulphur being now converted into sulphuric acid by the action of the nitric acid, nitrat of barytes was added, and from the precipitated sulphat of barytes the quantity of sulphuric acid, and of course, of sulphur, was estimated according to known proportions.

Some improvements may be suggested in this ingenious analysis. To separate the arsenic completely from the cobalt to which it adheres so obstinately, Mr. Chenevix's method may be advantageously adopted of adding nitrat of lead to the solution of the ore containing the arsenic fully acidified and partly united to the cobalt. The nitrat of lead will engage all the arsenic acid, and decompose the arseniat of cobalt. The arseniat of lead, being insoluble, remains at the bottom, the clear solution may then be decomposed by carbonat of potash, which will separate all the metallic contents, after which ammonia will dissolve the cobalt, and also any nickel that may be present, leaving the iron and any excess of lead that may remain. The ammoniated solution of nickel and cobalt may be thus separated, according to Mr. R. Phillips. ^c Let the solution be evaporated till the excess of ammonia is

driven off (which is known by a paper dipped in turmeric liquor no longer turning brown) in this state, if potash is added, and diluted with much water, the whole of the nickel is precipitated very speedily, but the cobalt remains suspended for a considerable time.

If copper be contained, after the arseniat of lead is precipitated, as in the last process, let the copper be separated by a bar of iron before the nitric solution is decomposed by alkalies.

In the large way cobalt and nickel may be considerably separated by scorification with nitre, the oxyd first produced being chiefly cobalt.^d

Cobalt was supposed by Brugnatelli^c to be capable of acidification. This was found by Darracq^f to be a mistake, but some of the particulars will shew some further circumstances relative to the union of arsenic acid and cobalt. If zaffre is digested in ammonia for some time, a red solution is formed, which when much evaporated deposits a yellow oxyd. The clear solution, after dryness, is again soluble in water, but not the yellow oxyd. If zaffre is boiled in water, a solution is also obtained, which when evaporated deposits a whitish oxyd, after which it crystallizes. The solution is sensibly acid, but is not a *cobaltic acid* as was supposed, but an arseniat of cobalt with excess of acid. The oxyd in both cases is not a pure oxyd of cobalt, but a mixture of cobalt with arsenic in some state of oxygenation.

The purest possible regulus of cobalt obtainable by any yet known process, is certainly that which is got from the ammoniated solution in the way above described, but as this is very expensive, chemists have endeavoured with some success to purify this metal by fusion. Lampsadius's process^g is the following. Project in a red-hot crucible a mixture of 4 ounces of smalt, 2 ounces of nitre, and half an ounce of charcoal. A strong smell of arsenic is perceived in the process, and a blackish grey mass remains, which is to be again mixed with nitre and charcoal, and deflagrated as before: then throw into the crucible 2 ounces of black flux and heat it strongly for an hour. This gives a tolerably pure regulus, weighing 6 drams. Powder it, and mix it with 1 dram of nitre and as much manganese, then put it in a luted double crucible, and heat it for an hour in a forge-furnace. The metal loses by this operation all its iron, and is nearly pure, excepting a small portion of arsenic, which may be further separated if necessary.

Tromsdorf's process is nearly similar.^h The

zaffre or smalt is to be twice detonated with nitre, washed in hot water to carry off the arsenic now united with the alkali of the nitre, and the residue digested in nitric acid, which will only touch the cobalt, leaving the iron in the highest state of oxidation. The purified oxyd of cobalt may then be reduced in the common way.

It may be observed on the subject of separation of iron from cobalt (as this is of consequence for manufacturing the finest possible colour from it) that when an alkali is added gradually to a mixed solution of the two metals, much of the iron precipitates before the cobalt falls, and this distinction is very obvious by the colour. Thus if carbonated potash be slowly added to nitrat of cobalt and iron, the first precipitate is a dull ochery slime, chiefly iron, after which the cobalt shews itself by a *violet* coloured precipitate, and thus a judicious addition of alkali (stopping when the violet colour is perceived) will alone purify the solution to a considerable degree.

Preparation of Zaffre, Smalt, and Azure.

All the zaffre and smalt of commerce is prepared in the large way in several parts of Germany, and particularly at Schneeberg in Misnia, which affords a very lucrative trade to Saxony.

The cobalt ore is put on the hearth of a furnace like a baker's oven,ⁱ so constructed that the flame of wood is reverberated on all sides over the surface, and soon heats it red-hot. A very dense arsenical vapour then begins to be given out, which is conveyed through a very long horizontal wooden square trough or chimney, sometimes as much as a hundred fathoms in length, where the arsenic is chiefly condensed, though Kunckel remarks that notwithstanding this enormous length of chimney, some of the vapours still escape through the further opening. The cobalt ore is calcined for some hours till it scarcely emits any more vapours, after which it is ground to powder, calcined a second time, again ground and passed through a very fine sieve. This powder is then mixed with two parts of powdered flints or quartz, moistened, and put in barrels, where it grows excessively hard. This forms the *zaffre* in the state in which it is exported. The real reason of adding the flints appears to be for some purposes of concealment, the exportation of the simple calcined oxyd being forbidden under heavy penalties.

Smalt, sometimes also called *zaffre*, and when

^a Tromsdorf. ^b An. Chim. tom. 33. ^c An. Chim. tom. 41. ^d An. Chim. tom. 26. p. 89. ^e Ph. Jour. vol. ix.
^f Kunckel in a note to Neri's Art de la Verrerie, p. 51.

finely powdered, *azure blue*, is a very deep blue glass, made of the calcined ore of cobalt and some vitrifiable ingredients, which is used as a colouring matter for a variety of purposes.^k The proportion of the vitrifiable basis to the cobalt depends on the estimated goodness of the latter and the result of small trials. On an average, equal parts of the calcined cobalt ore, of potash, and of ground flints are taken. These are first *fritted* and then made into glass, in pots similar to those of the glass-houses, requiring from 8 to 12 hours of fusion. When the blue glass is perfect, it is taken out with iron ladles and dropped into cold water to crack it in every direction and make it more easily reducible to powder, which is afterwards performed in a mill made of very hard stone inclosed in a wooden case. At the bottom of the glass-pots a quantity of regulus of bismuth is always found, (the ores of bismuth and cobalt being naturally mixed) and above it is a mixed alloy of arsenic, iron, and copper.

The grinding the blue glass is a work of labour and some difficulty. Several degrees of fineness are prepared by means of grinding and washing. These are all known by the general term of *smalt*, or, when in very fine powder, *azure*. The term *azure* however is also applied to lapis lazuli blue, a totally different substance.

As a colouring matter smalt is very valuable, both on account of the fine intense blue which it produces, and for its comparative cheapness, and because it is not altered by any heat. In this last respect it is superior to lapis lazuli, the colour of which is entirely and permanently destroyed in a red-heat, but smalt will not mix with oil colours, and therefore can only be very partially used. Smalt is used when mixed with starch to give a slight blue to linen, or rather to correct the tendency to yellow which linen acquires when worn.

Zaffre is prepared also in Bohemia, Wirtemberg, Silesia, Lorrain, and some other parts of the Continent, but the Saxon is preferred, and yields to the proprietors an annual revenue of 200,000 crowns^l.

COBALT, when rendered as pure as possible by the method above-described, has a steel-grey colour, not very resplendent, when slowly cooled appears reticulated in its texture, is brittle, and fusible at a heat about equal to that of cast-iron. However carefully it has been freed from iron, it remains magnetic, and therefore there is reason to suppose that this is a property inherent in the metal itself.

Cobalt burns in oxymuriatic acid gas with a bright white flame, but in a common fire it only oxidates when heated strongly in contact with air. In this case the oxyd is black. A hundred grains of reguline cobalt yield by this process 118 grains of the black oxyd,^m and hence 100 grains of the oxyd contain 84.75 of cobalt and 15.25 of oxygen. When it contains arsenic the oxyd becomes somewhat reddish.

Cobalt or its oxyd is soluble in most acids.

The sulphuric acid dissolves cobalt with difficulty, but better its oxyds. A sulphat of cobalt is formed by digesting the black oxyd, or common zaffre, or the precipitate from nitrated cobalt by carbonated potash, with four times as much sulphuric acid, somewhat diluted, or better, by distilling the acid from the cobalt to dryness and adding warm water to the residue. This solution evaporated slowly affords by cooling crystals of sulphat of cobalt, which are of a fine red when the metal is pure, but greenish when it contains nickel.ⁿ These crystals when slowly deposited are often aluminiform. They require 24 parts of cold water for solution, but only 15 parts when heated to 145°.

Nitric acid dissolves both cobalt and its oxyds copiously and with ease when gently heated and digested. The solution is red, or claret-coloured, or if holding iron, approaching to yellow. By evaporation it scarcely crystallizes, but leaves a saline deliquescent mass. This when further heated parts with all its acid, and leaves a dark red or violet-coloured oxyd.

Muriatic acid acts with great difficulty on cobalt, and only by repeated evaporation to dryness and adding fresh acid. But the oxyds of this metal it dissolves with much more ease. The solution is of a rose-red, but when heated, and much concentrated, it assumes a beautiful blue green, more approaching to blue as the cobalt is more free from iron. It is necessary that the solution be concentrated to produce this effect, and the dry salt shews it still more perfectly. This singular property of the muriat of cobalt was first used by Hellot in making a beautiful *Sympathetic Ink*. If characters be traced with this solution sufficiently diluted on paper, they are scarcely visible when cold, but when held before the fire they speedily assume a very bright beautiful blue-green. On cooling they again become invisible, and may at pleasure be made again to appear and depart by alternately warming and cooling. The paper should be no more heated than is necessary to produce the full effect. Any other solution of cobalt to

^k Encycl. Arts & Metiers. art. Saffre.

^l Gerhard.

^m Klaproth.

ⁿ Leonhardt.

which muriatic acid, or common salt, or muriatic acid of ammonia, or muriatic acid in any form is added, will answer as well. Hence the sympathetic ink is made at once by digesting zaffre in nitro-muriatic acid with a moderate heat for some time, and diluting the solution with just so much water as will make writing appear of a full green when hot and invisible when cold. As the nitric or muriatic acid is apt to corrode the paper, a still better ink is made by adding a little common salt to saturated acetite of cobalt, and diluting sufficiently with water.

The acetous acid only dissolves the oxyd of this metal. The solution is of a claret red. The use of repeated digestions in this acid to free cobalt from iron has already been mentioned.

The action of the arsenic acid on cobalt has also been noticed in the analysis of the cobalt ores. This solution is rose-red, and by evaporation leaves a violet mass, which again becomes red by digestion with hot water. This salt crystallizes without difficulty.

Most of the other acids dissolve the oxyd of cobalt, forming metallic salts but little known and of trifling importance.

Muriated ammonia digested with oxyd of cobalt also dissolves a portion and forms a green sympathetic ink.

A triple salt of oxyd of cobalt, ammonia, and nitric acid is also formed by adding ammonia to nitrated cobalt. Slowly evaporated, this forms regular crystals, partly cubical, partly in the shape of inverted hollow pyramids, according to the observations of Thenard.^a

This accurate chemist has also given some observations on the different states of oxidation which cobalt is capable of assuming. When pure potash is added to a solution of cobalt, the precipitated oxyd appears at first blueish, but in the air it becomes olive. When washed with oxymuriatic acid it passes through successive shades of brown red, and finally becomes black. This black oxyd therefore appears to be cobalt in the highest state of oxygenation, and when put into muriatic acid it dissolves therein with disengagement of oxymuriatic gas, and the solution, if concentrated, becomes green, but in the air it soon turns to purple, and immediately rose coloured if diluted with water. The brown and olive coloured oxyds also give oxymuriatic gas when dissolved in common muriatic acid, but less copiously than the black oxyd. Also if the black oxyd is heated of a cherry red for half an hour it becomes blue, which then dis-

solves in this acid without disengaging any gas. The green colour of the muriatic solution appears entirely to depend upon its concentration, for, when diluted, whether hot or cold it is rose-coloured. It appears therefore that the black oxyd is in its highest state of oxygenation, and the blue in the least, and that the olive and brown are in intermediate states. With regard to the rose and lilac colours so common to the solutions of cobalt, it is not certain that the oxyds when dry ever retain these shades, except when alloyed with arsenic or arsenic acid.

The fixed alkalies have scarcely any action on cobalt or its oxyds in the moist way, but ammonia dissolves the oxyd with ease, and thus separates it from iron and some other metals. The particulars of this solution have been mentioned in the analysis. The ammoniated cobalt is decomposed by potash, but slowly, whereas the ammoniated nickel which often exists in the same solution is precipitated thereby in a very short time.

Tincture of galls added to the acid solutions of cobalt give a yellowish white precipitate when free from iron.

Prussiat of potash causes a green precipitate when the cobalt is pure.

Cobalt unites with great difficulty with sulphur by artificial combination. Beaumé^p projected sulphur on cobalt in fusion, but the metal did not appear to be sensibly altered by it, and all the sulphur burnt off without difficulty. Monch^q found however that cobalt could be sufficiently sulphuretted to furnish a true cinabar when afterwards heated with the white oxyd of mercury.

All the hydrosulphurets combine with this metal without difficulty, both in the liquid and the dry way. Hydrosulphuret of potash added to a solution of cobalt turns it black, and gives a black precipitate, which an excess of the sulphuret redissolves.

Beaumé, on melting in a crucible 4 ounces of calcined cobalt ore, as much calcined gypsum, 6 ounces of salt of tartar, and 4 ounces of pitch, obtained a ready fusion of the whole mass in the sulphuret of potash formed in the process (the sulphuric acid of the gypsum being deoxygenated by the pitch and then uniting to the alkali), which gave a metallic-looking mass in large brilliant facets, beneath which was the earth of the gypsum and other scoria. This metallic sulphuret was of a golden yellow colour and weighed 3 ounces. It soon tarnished in the air and deliquesced entirely. Its solution in

^a Thenard. An. Chim. tom. 42.

^p Chymic. Exper.

^q Leonhardi Worterbuch.

water was decomposed by acids, which dissolved the cobalt leaving the sulphur. The sulphur adheres so strongly to the cobalt by the intermede of the alkali, that heat will not separate them. This sulphuret is much more fusible than cobalt itself.

None of the alloys of cobalt deserve particular notice. This metal does not unite, or only in very small proportion, with bismuth, silver and mercury. With gold, platina, copper, tin, iron, nickel, antimony and arsenic it unites easily and in various proportions. With lead, according to Gmelin, cobalt may be alloyed when wrapped up in sheet lead and covered with charcoal.

All proportions of cobalt not exceeding equal weights with the lead make an uniform alloy, brittle and hard in proportion to the quantity of cobalt.

When lead or bismuth are cupelled with cobalt, the latter is left behind in the form of a black oxyd.

The sole use of cobalt in the arts is for the fine blue which any of its oxyds gives when mixed and melted with any vitrifiable matter. The extent of the colouring power is perhaps more than that of any other of the metallic oxyds, for one grain of the pure oxyd will give a very full blue to half an ounce, or 240 grains of glass. The oxyd melted *per se* gives so intense a blue as to appear perfectly black, except just at the thin edges of the sharp fragments when broken. Manganese greatly impairs the clearness of the colour, giving a strong admixture of muddy purple, but this effect is corrected by adding a little arseniat of soda or other arsenical salt. (For further particulars on this subject see the article GLASSES coloured.)

Cobalt is also said to be contained in small quantity in some of the fine Chinese metallic alloys, but its use is very doubtful, and the dearth of the metal would prevent it from being used to any extent for such purposes in Europe.

It may be added that in most of the experiments on the alloys and the sulphurets of this metal, it has been used in only its common state of purity, that is to say, still alloyed with arsenic and iron, and probably with nickel.

The affinities of cobalt are stated to be in the moist way as follows: the gallic, oxalic, muriatic, sulphuric, tartareous, nitric, phosphoric, fluoric, succinic, citric, acetic, arsenic, boracic, prussic and carbonic acids, and ammonia.

COCOLITE.^a The colour of this mineral is grass-green passing to olive or blackish green. It occurs in masses composed of small granular

distinct concretions like seeds or minute kernels (whence its name.) These concretions are somewhat angular, and shew a tendency to crystallization. They have a considerable vitreous lustre. The fracture of the grains is lamellar in two different directions, seemingly at right angles to each other: the fracture of the mass is granular. It is translucent; sufficiently hard to scratch glass, and brittle. Sp.gr. 3.37.

Coccolite is very difficultly fusible *per se* before the blowpipe. According to an analysis by Vauquelin, it consists of

50	Silex,
24	Lime,
10	Magnesia,
7	Oxyd of iron,
3	Ditto of manganese,
1.5	Alumine.

95.5
4.5 loss

100.0

This mineral has been lately discovered by Abildgaard, in veins at Arendahl in Norway, at Nerika in Sweden, and in the iron mines of Hellesta and Asebo in Sudermania. It has scarcely yet acquired a permanent station in systems of mineralogy, and will probably be ranked as a variety of augite.

COCHINEAL. *Coccus Cacti* Linn.

The substance known in commerce by the name of cochineal, is in the form of hemispherical shrivelled grains, about an eighth of an inch long, of a deep reddish purple colour, and covered more or less with a white down; they are very light, and easily rubbed to powder between the fingers. The merchants distinguish at least two kinds, called *grana fina* and *grana sylvestra*; of these the latter is not more than half the size of the former, and covered with a much longer down; on which account it always bears a much lower price in the market.

Cochineal was first introduced into Europe from Mexico about the year 1523, and was for some time supposed to be the berry or seed of a vegetable. It was at length however ascertained that these grains were the females of a particular species of insect, called by naturalists *Coccus cacti*, and of the same genus as the Kermes (*Coccus Ilcicis* Linn.)

The cochineal insect is a native of Mexico, and was in common use among the inhabitants as a dying-drug when the Spaniards first came

^a Haüy, Brochant.

into the country; since that period its use has become more and more general, not only in Europe, but in various parts of Asia, and as almost the whole of this valuable commodity is still raised in Mexico, Peru, and the adjoining Spanish settlements, it becomes every year an object of more sedulous cultivation than before.

The wild cochineal (*grana sylvestra*) feeds upon most of the species of cacti that are natives of Mexico, requires no particular care or attendance, and may be gathered six times in the year, there being so many generations of this insect in a twelvemonth: the time of collecting the cochineal is just before the female produces its young, as the animal perishes immediately afterwards. The cultivated cochineal (*grana fina*) is supposed to have originated from the wild kind: but this opinion appears very doubtful. If it be granted that the superior size of the former, and its want of those long white hairs or down which cover the latter may be the effect of domestication, there still remain two other distinctive characters which appear to be original; these are, its feeding only upon one species of cactus, the cochenillifer, or nopal, and its producing only three broods or generations in the year. The management of the cochineal insect is simple, but requires incessant attention. At the third annual gathering of cochineal a certain number of females are left adhering to branches of the nopal, which are then broken off and kept carefully under cover during the rainy season; when this is over, the stock of cochineal thus preserved by each cultivator is distributed over the whole plantation of nopals, where they soon multiply with great rapidity. In the space of two months the first crop is gathered by detaching the insects with a blunt knife, after which they are put into bags and dipped in hot water to kill them, and finally dried in the sun, by which they lose about two-thirds of their weight. The proportion of colouring matter contained in equal portions of the cultivated cochineal, the wild cochineal of Mexico and an inferior kind from St. Domingo, is as eighteen, eleven, and eight.^a The average quantity of fine cochineal annually consumed in Europe amounts, according to Dr. Bancroft, to 600,000 lbs. When thoroughly dry it experiences no change from long keeping in close packages: Hellot affirms that he used some which was 130 years old, and found it as good as if it had been quite fresh.

The colouring matter of cochineal may be

extracted either by water or alcohol. The alcoholic solution is of a deep crimson colour, and on evaporation leaves a transparent residuum of a deep red, which has the appearance of a resin. The aqueous solution or decoction of cochineal is of a violet crimson colour, and this if evaporated slowly to the consistence of an extract, and then digested in alcohol, communicates to this menstruum a colour similar to the preceding spirituous solution, a residuum of the colour of wine lees being left behind.

The aqueous decoction of cochineal if mixed with a little sulphuric acid assumes a red colour, inclining to yellowish, and a small quantity of a fine red precipitate is thrown down. Muriatic acid produces nearly the same change of colour, but occasions no precipitate. A solution of tartar changes the cochineal decoction to a yellowish red, and a small quantity of a pale-red precipitate is slowly deposited: the supernatant liquor is yellow, but on the addition of a little alkali it becomes purple, the precipitate being at the same time redissolved. Alum brightens the colour of the infusion and gives it a redder hue; a crimson precipitate is deposited, and the supernatant liquor retains a similar tinge. A mixture of alum and tartar produces a brighter and more lively colour, inclining to yellow: a precipitate is thrown down, but much paler and less in quantity than where alum alone is used. Nitrio-muriat of tin throws down a copious crimson sediment, not a particle of colouring matter remaining in the liquor. Sulphat of iron forms a brownish-violet precipitate, and the supernatant liquor is of a dilute yellowish-brown. Sulphat of zinc forms a deep violet, and acetite of lead a purple-violet precipitate, the liquor in both cases being perfectly colourless. Sulphat of copper changes the colour of the decoction to violet, and a small sediment of the same colour very slowly subsides.

Cochineal is used either as the basis of that fine pigment called carmine and lake-red, or as a dying drug to tinge wool and silk, either scarlet or crimson, or the finer kinds of violet.

The preparation of carmine and lake-red is so valuable a process, and one so easily kept secret, and its perfection depends so much on nicety of manipulation, that none of the published methods in all probability will afford it of the very best quality. The following is perhaps the best of those which have yet been made public, and if carefully pursued will yield a pigment greatly superior to the carmine that is generally met with.^b

^a Berthollet on Dying, II. p. 169.

^b Alton Cours de Chimie, II. p. 174.

Into a 14 gallon boiler of well tinned copper, put ten gallons of distilled or very clear river or rain water (spring-water will not answer the purpose). When the water boils sprinkle in by degrees a pound of fine cochineal previously ground in a clean stone mortar to a moderately fine powder: keep up a moderate ebullition for about half an hour, and then add three ounces and half of crystallized carbonat of soda: in a minute or two afterwards draw the fire, and then add to the liquor an ounce and a half of Roman alum very finely pulverized; stir the mass with a clean stick till the alum is dissolved, then leave it to settle for 25 minutes: draw off the clear liquor with a glass syphon, and separate the sediment from the residue by straining it through a close linen cloth. Replace the clear liquor in the boiler and stir in the whites of two eggs previously well beaten with a quart of warm water; then light the fire again and heat the liquor till it begins to boil, at which time the albumen of the eggs will coagulate and combine with the earth of the alum and the finest part of the colouring matter: this sediment is the carmine, and being separated by filtration, and well washed on the filter with distilled water, is to be spread very thin on an earthen plate and slowly dried in a stove: after which it is ready for use. The finest part of the colouring matter of the cochineal being thus separated, the residue may be employed in the preparation of red lake in the following manner. Add two pounds of pearlash to the red liquor from which the carmine was precipitated, and return it into the boiler together with the dregs of the cochineal, and boil the whole gently for about half an hour; then draw the fire, and after the sediment has subsided drain off all the clear liquor into clean wooden or earthenware vessels (the latter however are the best, as the alkaline solution is apt to dissolve a little extractive matter from the wood). Then pour upon the sediment a second alkaline ley prepared by dissolving a pound of pearlash in two gallons of water, and boil this also upon the dregs for half an hour, by which process the whole of the colouring matter will be exhausted. Separate by filtration the liquor from the dregs, and return both the alkaline solutions into the copper. When this bath is as hot as the hand can bear, add by degrees three pounds of finely pulverized Roman alum, observing not to add a second portion till the effervescence from the first has entirely subsided. When the whole of the alum has been put in, raise the fire till the liquor sim-

mers, and continue it at this temperature for about five minutes, at which time if a little is taken out and put into a wine glass, it will be found to consist of a coloured sediment diffused through a clear liquor. After standing quiet a while the greater part of the clear supernatant liquor may be poured off, and the residue being placed on the filter, will there deposit the coloured lake, which after being accurately washed with clean rain water, may be covered with a cloth and allowed to remain for a few days till it is half dry: it is now to be separated from the filter, to be made up in small lumps and placed in a stove to dry. By this management a pound of good Mexican cochineal will afford one ounce and a half of carmine, and about a pound and a quarter of red lake.

If the colour is required to incline somewhat towards scarlet, this may be effected by grinding along with the cochineal from a quarter to half an ounce of the best annotta.

For the use of cochineal in DYEING, see that article.

COELESTINE. *Celestin*, Warner. *Strontiane Sulphatée*, Haüy.

The native sulphat of strontian, called coelestine, from the bluish tint which it generally assumes, is divided into three varieties, the fibrous, foliated, and compact.

1. Fibrous coelestine. *Fasriger celestin*.

Its colour is between indigo-blue and bluish-grey, passing sometimes into milk-white, by keeping it becomes white or colourless. It occurs in mass, in plates and crystallized. Its longitudinal fracture presents a shining lustre, its cross fracture is glistening and pearly. Its longitudinal fracture is curved-fibrous, approaching to foliated; its cross fracture is splintery. It is translucent; somewhat softer than fluor; easily frangible: sp. gr. = 3.83.

According to the analysis of Klaproth* it contains

58	Strontian
42	Sulphuric acid,
—	with a trace of iron
100	

It occurs in ferruginous marl in the vicinity of Bristol, and at Frankstown in Pennsylvania.

2. Foliated Coelestine. *Blattriger celestin*.

Its colour is milk-white, passing into blue: it occurs in mass, or crystallized.

1. In strait prisms, with rhomboidal bases (which is its primitive form) the angles of which are $104^{\circ}-48'$ and $75^{\circ}-12'$.

2. In cuneiform octahedrons.

* Analyt. Ess. I. p. 394.

3. In short hexahedral prisms.

Its lustre is glistening or shining: its fracture is imperfectly foliated: it is semi-transparent, rarely transparent. In hardness and frangibility it resembles the preceding variety. Sp. gr. = 3.5.

It has been analysed by Vauquelin, and found to contain

54 Strontian
46 Sulphuric acid

100

It occurs in the neighbourhood of Bristol in loose nodules, and very finely crystallized in Sicily.

3. Compact coelestine. *Dichte celestin.*

Its colour is bluish or yellowish-grey. It occurs in mass and in flattened spheroidal and kidney-shaped pieces. Its fracture is fine-splintery, passing into foliated. It is opaque, and sometimes translucent on the edges. It is soft and easily frangible. Sp. gr. = 3.59. It has been analysed by Vauquelin, and consists of

91.42 Sulphat of Strontian
8.33 Carbonat of lime
0.25 Oxyd of iron

100.00

It occurs imbedded in clay in the gypsum quarries of Mont Martre, near Paris.

COHOBATION is the repeated exposure of one substance to the chemical action of another substance, either by returning the latter when driven off by distillation, or by supplying a fresh quantity after the action of the first has been exhausted.

COLCOTHAR is the red oxyd of iron which remains after the distillation of aquafortis in the large way, when the sulphat of iron is the salt used for the decomposition of the nitre. Colcothar is iron in its highest state of oxygenation, and when washed, and properly sifted and levigated, it is much used in polishing iron and other hard bodies.

COLD. The opinions relative to the nature of cold are mentioned under the article *Caloric*. For the different means of producing artificial cold, see also **FREEZING**.

COLOPHONY is a hard black resin, artificially prepared from *Turpentine*, (which see).

COLOURING Matter. For the nature of colouring matter see the article *Dyeing*. Some of the most important of these, such as *cochineal*, *indigo*, *madder*, &c. have been analyzed by chemists, and are separately noticed.

COLUMBIUM is the name given by the discoverer, Mr. Hatchett,* to a substance hitherto undescribed, and apparently metallic, found in a certain specimen in the British Museum, sent from some part of North America, probably Massachusetts.

The specimen is a dark brownish grey ore, imperfectly lamellated in its longitudinal fracture, of a vitreous lustre, moderately hard and brittle, not magnetical, its specific gravity is 5.918.

The following analysis shews it to consist of iron and a peculiar unknown substance in the proportions of about one of the former to 3 of the latter.

The ore was successively boiled with muriatic, nitric, and sulphuric acids. Of these, the sulphuric acted the most powerfully, and the muriatic the next, but neither of them produced a full solution of the ore but appeared only to act on a portion of the iron which it contained.

It was therefore necessary to pursue the admirable method of previously breaking the cohesion of its parts by fusion with alkali, so advantageously employed by Klaproth and other modern analysts in the examination of refractory minerals.

The ore was accordingly powdered and heated in a silver crucible with five times its weight of carbonat of potash. When the alkali began to melt, an effervescence took place, owing to the union of the ore with the potash, after which the whole subsided into a mass, greyish-brown when cold. Boiling water dissolved a portion, making a clear alkaline solution. The insoluble residue was digested in muriatic acid, which dissolved another portion, but still leaving a residue. This last was again fused with carbonat of potash, and gave as before a portion soluble in water, another on muriatic acid, and a residue. This last entirely disappeared by continuing the same plan, and thus the whole was resolved into several similar portions of an alkaline solution, and an equal number of muriatic solutions. The alkaline solutions supersaturated with nitric acid gave a white flocculent precipitate, not soluble in an excess of the same acid. The muriatic solutions were mixed, saturated with ammonia, and gave an ochery precipitate, the iron of which was dissolved in nitric acid, and the remainder was now white, and resembled the precipitate from the alkaline solutions.

The nitrat of iron gave by ammonia 42 grains of oxyd of this metal (from 200 of the

* Phil. Trans. for 1802.

ore) and the white flocculent matter weighed about 155 grains. This last being obviously a peculiar substance was examined separately, and was found to have the following properties, which (collectively taken) distinguish it from any other known substance, and at present may be considered as pure *columbium*, or rather as the supposed oxyd (but as yet irreducible) of a metal to which the name of columbium has been given.

This substance is white and not very heavy. It has no taste, and is scarcely soluble in water, but, laid on litmus-paper, it turns it red, and hence it may be inferred to be slightly acid.

Under the blow-pipe it is not fusible *per se*, nor with borax, but readily, and with effervescence with the carbonats of soda and potash. Phosphat of ammonia, or phosphoric acid dissolve it also in this way, and produce a purplish blue globule.

Nitric acid has no action whatever upon it.

Boiling sulphuric acid is the best of the acid menstrua for this substance, and dissolves it easily, but the greater part of the solution is decomposed by dilution with water, and a heavy insoluble sulphat of columbium subsides as a white powder. It requires some minutes for this effect to take place.

Prussiat of potash, added to the sulphuric solution produces immediately a copious beautiful olive precipitate.

Tincture of galls gives an orange-coloured precipitate.

All the alkalies decompose the sulphuric solution, but when in excess do not redissolve the precipitate unless heated.

Boiling muriatic acid dissolves the white precipitate from the solution of columbium, in potash, by an acid, if taken wet and recently separated.

A muriat of columbium is thus produced which is not crystallizable. A piece of zinc immersed in this solution gives a white flocculent precipitate, but nothing in a metallic state.

The fixed alkalies dissolve columbium in the moist way as well as by fusion. The solution in potash, when evaporated, gives a white glittering scaly salt resembling boracic acid in appearance, and of an acrid alkaline flavour.

Columbium is inferred to be of a metallic nature, by forming coloured precipitates with prussiat of potash and galls, by being separable from its solution by zinc, and by colouring phosphoric acid melted with it, but the attempts to reduce it to the reguline state by fusion with charcoal, have not succeeded.

From its reddening litmus it appears to be in the state of an acid.

COMBUSTION is the rapid decomposition of any body attended with the production of **LIGHT** and **CALORIC**. In all the great processes of combustion that are constantly going on, the presence of **OXYGEN** in one form or other is essentially requisite, which appears to be the great agent of this decomposition; as the *products* of combustion consist principally of the combustible materials united with the oxygen employed. As the evolution of light and heat are included in the popular idea of combustion, it seems proper to retain these phenomena in the definition, and thereby to distinguish it from *oxygenation* in which they are wanting. It must be acknowledged however that the products of combustion, in many instances, do not sensibly differ from those of simple oxygenation, and hence Lavoisier was led to use the term *slow combustion*, to express oxygenation without the sensible evolution of light and heat. This has led to some probable opinions on the nature of oxygen, which will be mentioned under that article.

CONGELATION. See **FREEZING**.

COPAL. This singular kind of resin is brought principally from South America, and partly from the East Indies, and is a natural exudation from a large tree which hardens on exposure to air. Copal is one of the hardest of the resins, and easily reducible to a very fine powder. It is beautifully transparent, and chiefly of a light-lemon colour, sometimes inclining to orange, but the colour of the finest sort is so faint that when spread thinly over any surface as a varnish it is not perceptible, and only gives a fine hard smooth transparent glazing. It is this union of hardness with colourless transparency that makes copal so eminently valuable as a varnish for pictures, white-wood works, and a variety of other purposes.

The common resins are characterized by being insoluble in water, soluble in alcohol, essential oils, and ether, and highly combustible. Copal agrees with the resins in combustibility and all external characters, but it cannot be dissolved in the above menstrua without particular pains, and requires them to be in a state of extreme purity. In these qualities therefore it appears to hold an intermediate state between the true resins and amber, resembling the former by being soluble in oily substances which do not touch amber, and the latter by greatly resisting the action of alcohol.

As it is a process of some nicety to produce a true solution of copal fit for the purpose of a varnish without impairing the colour, some of the directions laid down by practical artists may here be inserted. The following is given by Mr. Sheldrake^a as the result of long practical observation. Reduce two ounces of copal to *coarse* powder (not fine) put it into a glass vessel and pour thereon a mixture of one pint of the best oil of turpentine with one-eighth of spirit of sal ammoniac, previously well shaken, cork the glass, leaving a small hole through the cork, to allow the escape of the spirituous vapour, and speedily heat it to that point at which the bubbles may be counted as they rise to the surface. Continue this heat, neither increasing nor lessening it, till the solution is complete, or till no more will dissolve. The mixture becomes somewhat milky at first, then the upper surface clears, whilst the copal swells, softens, becomes opaque, and gradually diffuses itself through the spirit, dissolving therein. It should seem that this process requires much nicety of management in regulating the heat, for if ever this is increased the bits of copal resume their transparency,^b no longer coalesce, and remain afterwards perfectly insoluble. It is also of the utmost consequence that the oil of turpentine be of the best sort, and very highly rectified. The vessel should not be opened till quite cold, otherwise the sudden escape of the vapour will carry out with it a great part of the solution. This varnish is of a rich deep colour when viewed in the bottle, but gives no sensible colour when laid on.

Copal may also be united with oil of turpentine very conveniently by the intermede of other essential oils, particularly oil of spike, or oil of lavender. The following process is given by M. Tingry.^c Put 2 ounces of essential oil of lavender into a glass matras heated by a lamp, or over a moderate fire, add thereto when very warm one ounce of copal grossly powdered, and at different times stirring it with a stick of white wood; when the copal is dissolved add 6 ounces of boiling oil of turpentine, dividing it into three doses at as many different times, and keep stirring till the whole is uniformly mixed. This varnish will be of a fine gold colour, very durable and brilliant.

Ether is also a good solvent for copal. ^d Reduce half an ounce of copal to fine powder, and put it by small portions into a flask containing 2 ounces of cold fulphuric ether of the purest

kind. Shake it well, and in some hours the solution will be complete. If the liquor is not perfectly clear add more ether.

The remarkable effect of camphor in promoting the solution of the resins has been mentioned under that article. With none is this property shewn more strikingly than with copal. When the two are separately powdered and then mixed, the copal absorbs the camphor, swells, and softens into one coherent mass which will remain for six months of the same pasty consistence, though kept in a warm dry room.^e By the intermede of camphor, copal may be completely dissolved in alcohol. Dissolve half an ounce of camphor in a pint of alcohol, put it into a glass vessel over a moderate fire, and add four ounces of copal in small pieces, continue the heat that the bubbles may be counted, till the solution is complete. A part of the copal will separate when the liquor is cold, but enough will be retained to give a fine colourless varnish.

Camphor also assists the solution of copal in oil of turpentine according to the following process, also given by Mr. Sheldrake. Dissolve half an ounce of camphor in a quart of oil of turpentine, take a piece of copal the size of a walnut, bruize it into coarse powder, add it to the camphorated oil of turpentine, and *bring it to boil as soon as possible*, then keep it gently boiling for an hour, and enough of the copal will be dissolved to form a good varnish. The vessel (glass or tin) in which the solution is made should be closely corked, leaving only a very small hole for the escape of the vapour to prevent the vessel from bursting, an accident which (from the extreme combustibility of the ingredients) might be attended with very serious consequences.

The above process should be followed precisely, for if the camphor is not added first, or if the copal is in fine powder, these two substances at once unite, forming a mass like birdlime at the bottom of the vessel, and the solution will not go on.

Copal may also be dissolved according to Demmenie,^f by being suspended in a glass receiver over alcohol or oil of turpentine, and applying heat to make the liquor boil. The vapours arising from it liquify the copal which falls in drops into the boiling fluid, and immediately dissolves.

For a copal varnish which is to unite the qualities of transparency and durability, to a

^a Transact. of the Society of Arts.

^b Phil. Jour. vol. 9. 8vo.

^c The Painter's and Varnisher's Guide, 1804.

^d Tingry.

^e Sheldrake.

^f Phil. Jour. vol. 2. p. 142.

certain degree of pliability, M. Tingry gives the following receipt. Take of powdered copal 2 ounces; of oil of lavender 6 ounces; of camphor one drachm; and of oil of turpentine as much as is wanted to give the requisite consistence. The camphor and oil of lavender are to be separately liquefied, then the copal dissolved therein, and lastly the oil of turpentine added boiling-hot and incorporated by stirring. This the author considers as fit for the ingenious process of varnishing wire gauze, in the Chinese manner, for lanterns, to be used where a lighter and less brittle material than glass is wanted.

In the composition of the drying-oil varnishes with amber or copal, it is well known that a greater heat is required than in the former spirit varnishes, as it must be sufficient to liquify the resin before it will unite with the oil. Both amber and copal have the disadvantage of becoming brown and coloured by a melting heat, applied in the common way, and hence it is a great object to find some method of melting these resins without impairing that transparency for which they are so much valued.

M. Tingry finds this object to be considerably attained by inclosing the copal in a wire-net hanging in the centre of a small furnace of peculiar construction, and with a very moderate and well regulated fire, whence the copal, as soon as liquefied, falls down through a conducting tube, and may be thus dropped in a liquid state into hot drying oil set below to receive it. They immediately unite, and when afterwards tempered with sufficient hot oil of turpentine, a fine drying oil varnish is formed, which has but little colour and retains its transparency.

If the melted copal is received into water a small quantity of oil is separated, which is found floating at the top, and the copal appears to be rendered thereby somewhat more soluble in different menstrua.

As copal is expensive it is sometimes adulterated with gum anime when very transparent. The latter is distinguished by being more friable, and for giving a sweet odour when rubbed. Copal will unite with other resins in compound varnishes, and many of the liquors commonly sold for copal varnish, contain only a small portion of copal, the other resinous basis being composed of mastich, sandrach, and others of the most colourless resins.

COPPER. *Cuprum*, Lat. *Kupfer*, Germ. *Cuivre*, Fr.

Copper is a malleable and ductile metal of a pale-red colour with a tinge of yellow. It is

soluble with effervescence in nitrous acid, to which it gives a sky-blue colour: on the addition of liquid ammonia a green precipitate is thrown down, which is re-soluble in an excess of ammonia, forming a very rich purplish-blue fluid, and from this, if slightly supersaturated with muriatic acid, the copper is again precipitable in its metallic form by a bar of clean iron.

The ores of this metal are very numerous,^a and may with most convenience be arranged under the eight following families.

I. Family. NATIVE COPPER.

Sp. I. Native Copper. *Gediegen Kupfer*. *Cuivre natif*.

Its colour is a clear copper-red, often tarnished externally yellowish, blackish or greenish. It occurs in mass, disseminated, in leaves, in rolled pieces, in grains, capillary, filiform, moss-like, dendritical and crystallized.

1. In cubes, either entire or truncated at the edges and angles.

2. In octahedrons, either regular or combined with the cube.

3. In pyramidal dodecahedrons formed of two six-sided pyramids, with a short six-sided prism interposed.

The crystals are small or very small, seldom single and most commonly implanted in each other, forming dendritical or clustered masses. Its external lustre is casual, its internal is glistering and metallic. Its fracture is hackly: when cut or rubbed it has a shining metallic lustre. It is not very hard, is malleable and flexible without being elastic, and difficultly frangible. Sp. gr. of the Hungarian 7.72, of the Siberian 8.58.

It is fusible before the blowpipe, and appears to be pure copper.

It occurs in veins and beds in quartz and granite, in slate, porphyry, serpentine, hornstone and limestone, accompanied by various other ores of copper, particularly the red oxyd, malachite and copper pyrites, with galena, horn-silver, native silver, calcareous spar, heavy-spar and fluor.

It is very generally, though not often very abundantly diffused. The finest specimens come from the Tourinski mines on the eastern side of the Uralian mountains, from Herrngrund in Hungary, from Saxony, the Hartz, Fahlun in Sweden, and Cornwall. It is said to be remarkably abundant in Japan and Brazil, and to contain a considerable proportion of gold. It is also procured in quantity from the Copper-mine river within the Arctic circle in America.

^a Kirwan, Haüy, Brochant. Jameson. Emmerling, Bournon in Phil. Trans.

II. Family. OXYD OF COPPER.

Sp. II. Ruby Copper. *Florid red Copper ore*, Kirw. *Roth Kupfererz*, Werner. *Cuivre oxydé rouge*, Haüy.

Of this species there are the following varieties.

Var. 1. Lamellar R. C. *Blattriges R. K.* Werner.

Its colour is dark cochineal-red, inclining sometimes to lead-grey; when crystallized it is often of a full carmine-red. It occurs in masses, disseminated and crystallized.

1. In cubes.

2. In aluminiform octahedrons, either perfect or truncated on the angles or on the edges and angles.

The crystals are small and very small, and are often aggregated together by their sides; their surfaces are smooth and shining. The internal lustre of this mineral is more or less shining, and is intermediate between metallic and that of the diamond. Its fracture is imperfectly foliated passing into granular uneven. It occurs sometimes in granular distinct concretions passing into the compact variety. When in masses it is usually opaque or at most translucent on the edges; the crystals are transparent, verging into translucent. It gives a brownish brick-red streak, is moderately hard, brittle and easily frangible. Sp. gr. 3.95.

By exposure to the blowpipe on charcoal it is easily reducible to a metallic bead without emitting either odour or smoke. It dissolves in the nitrous and muriatic acids, in the former with and in the latter without effervescence. According to the analysis of Mr. Chenevix, it consists of

88.5 copper,
11.5 oxygen.

100.0

It is met with chiefly in veins, and appears to be peculiar to primitive mountains: the substances with which it is accompanied are native copper, malachite, and brown iron ochre; sometimes mountain green, copper pyrites and other ores of this metal, also quartz, calcareous and heavy spars.

It is found in Cornwall, in Hungary, Saxony, the Hartz, Siberia, Peru and Chili.

Var. 2. Capillary R. C. *Haarformiges R. K.* Werner.

This variety differs from the preceding in being of a somewhat lighter colour, superior lustre, and being composed of small capillary crystals and thin flakes.

Var. 3. Compact R. C. *Dichtes R. K.* Wer.

It occurs in masses and disseminated but never crystallized: its internal lustre is glimmering, semi-metallic. Its fracture is even, and it is opaque. In other respects it agrees with Var. 1.

Sp. III. Tile-red Copper. *Brick-red Copper*, Kirw. *Ziegelerz*, Werner.

This species is found in two states, indurated and earthy.

Var. 1. Indurated T. C. *Festes Z.* Werner.

Its colour is intermediate between hyacinth and brownish-red, and passes on the one hand into lead and dark steel-grey, and on the other into blackish or reddish brown. It occurs massive and disseminated. The reddish kind has a glimmering lustre and flat conchoidal fracture, the browner kind has a somewhat resinous lustre and small conchoidal fracture. It acquires a lustre by friction, is moderately hard and brittle.

When exposed to the blowpipe it becomes black and is infusible without addition. Borax is tinged by it of a dirty green. It appears to be an intimate mixture of compact ruby copper with brown iron ochre, and its produce of copper varies from ten to fifty per cent.

It occurs in veins with ruby copper, malachite, copper pyrites and iron ochre. It passes into brown iron stone.

Var. 2. Earthy T. C. *Erdiges Z.* Werner.

Its colour is hyacinth-red, passing into reddish or yellowish-brown. Its texture is between friable and solid. It occurs in masses, disseminated, and incrusting copper pyrites. It is without lustre, has an earthy fracture and slightly soils the fingers. In its other characters it agrees with the preceding variety.

III. Family. SULPHURET OF COPPER.

Sp. IV. Vitreous Copper. *Kupferglas*, Wer. *Cuivre vitreux*, Broch. *Cuivre sulfuré*, Haüy.

Its colour is dark lead-grey passing into blackish grey, it often presents a superficial steel-coloured tarnish. It occurs in masses, disseminated, or crystallized.

1. In cubes.

2. In octahedrons.

3. In hexahedral prisms, either regular or terminated by trihedral summits placed on three of the lateral sides.

The crystals are small and very small. Externally they are shining; internally they exhibit a glistening metallic lustre. The fracture is fine grained uneven, passing into conchoidal and thence into even. It gives a shining streak, is blackish when pulverized; commonly breaks short under the knife, and is easily frangible. Sp. gr. 4.1 to 5.4.

It effervesces with nitrous acid, and when exposed to the blowpipe it gives a metallic button generally of a steel grey colour and attractable by the magnet.

When pure it appears to be a simple sulphuret of copper, and is found occasionally in this state in Cornwall, when it consists, according to Chenevix, of

81 Copper,
19 Sulphur.

100

It is generally however mixed with iron in the proportion of from 3 to 6 per cent. Klaproth analysed a specimen from Siberia, which contained

78.5 Copper,
18.5 Sulphur,
2.25 Iron,
0.75 Silica.

100.00

It occurs in veins and beds in primitive and floetz mountains, accompanied by copper pyrites and other ores of this metal. It is not very abundant, but is found in various places, especially Cornwall, Hungary, Saxony, Norway and Siberia.

Sp. V. Purple Copper. *Buntkupfererz*, Werner. *Cuivre pyriteux hepatique*, Haüy.

Its colour is intermediate between copper-red and tombac-brown; on exposure to the air it becomes first reddish, then violet azure and sky-blue, and lastly green; its general tinge however is blue, and the green only occurs in spots. It is found in mass or disseminated, or superficial, or, according to some writers, crystallized in octahedrons. Internally it is shining, with a metallic lustre. Its fracture is small and imperfect conchoidal, passing into fine-grained uneven. It takes a polish by friction, and when pulverized is of a reddish colour. It is so soft as in some degree to yield to the nail; and is easily frangible. Sp. gr. about 5.

It effervesces with nitrous acid, though by no means so strongly as the preceding species, and melts readily before the blowpipe without vapour or smell.

It is looked upon by Bournon as a proper double sulphuret of copper and iron. From the analysis by Chenevix of several Cornish specimens of a nickel-red colour, it appears to consist of

60 to 65 Copper,
15 — 18 Iron,
17 — 25 Sulphur.

Klaproth has analysed two specimens, one

from Hitterdahl in Norway, and the other from Rudelstadt in Silesia, with the following result.

69.5 — 58 Copper,
19 — 19 Sulphur,
7.5 — 18 Iron,
4 — 5 Oxygen.

100.0 100

It is to be observed however that the oxygen in these analyses was only inferred from the deficiency of the three first ingredients when compared with the whole quantity previous to analysis.

This ore occurs in beds, veins, and disseminated in rocks of different formations: it appears however to be most frequent in primitive beds. It is usually accompanied by vitreous copper and copper-pyrites, and not unfrequently by garnet. It is found in Cornwall, and in most of the copper-mines on the Continent.

Sp. VI. Grey Copper. *Fahlerz*, Werner. *Cuivre gris*, Haüy.

Its usual colour is steel-grey of more or less intensity, which often passes into iron-black and lead-grey; some varieties incline towards yellow, and others again present superficial iridescent colours. It occurs in mass or disseminated, or investing, and is then often specular, or crystallized in regular tetrahedrons and their modifications. The crystals are small and rarely middle-sized, with shining surfaces. Internally it is glistening or shining, with a metallic lustre. The fracture is coarse and small grained uneven, inclining to imperfect-conchoidal. It gives a black powder passing into reddish-brown. It is moderately hard, brittle and easily frangible. Sp. gr. when pure 4.46 to 4.56, that of the more compound varieties rises to 4.86.

It is considered by Bournon as a proper double sulphuret of copper and iron, and differs from the preceding species in colour, crystalline form, specific gravity, and proportion of component parts. Some brilliant crystals of this species, in the form of tetrahedrons with doubly bevelled edges and the solid angles truncated, from Cornwall, were analysed by Chenevix, and found to consist of

52 Copper,
33 Iron,
14 Sulphur,

99

A similar result was also obtained from the analysis of some specimens of the same in mass. But though copper, iron and sulphur appear to

be the only necessary ingredients of this ore, yet it is most frequently found to contain also antimony, silver and lead, though in extremely variable proportions. Some varieties from Transylvania, Alsace, the Hartz, Saxony, Hesse and Dauphiné, examined by Mr. Chenevix, were found to contain, besides the substances above mentioned, a portion of antimony varying from 5 to 38 *per cent.* but neither lead nor silver. Two of the more complicated specimens, one from Kremnitz and the other from Andreasberg, have been analysed by Klaproth with the following results:

Copper	31.36	—	16.
Iron	3.30	—	13.
Sulphur	11.5	—	10.
Antimony	34.09	—	16.
Silver	14.77	—	2.25
Lead	0	—	34.
Silex	0	—	2.5
	<u>95.02</u>		<u>93.75</u>

Finally, a specimen from Piedmont has been examined by Napione, and found to consist of

Copper	29.3
Iron	12.1
Sulphur	12.7
Antimony	36.9
Silver	0.7
Arsenic	4.
Alumine	1.1
	<u>96.8</u>

It occurs in veins in slate and some other of the newest primitive rocks, and in beds in the transition and floetz-rocks. It is accompanied by copper-pyrites, galena, manganese, spathose iron, quartz, heavy spar and fluor, also, though rarely, with malachite and azure copper. When it contains a notable proportion of silver, it is worked as an ore of that metal, and will accordingly be mentioned again under silver.

It is found in Cornwall and Ayrshire, and in many parts of the Continent.

Sp. VII. Copper Pyrites. *Yellow Copper ore*, Kirw. *Kupferkies*, Werner. *Pyrite cuivreuse*, Haüy and Brochant.

Its colour is a deep brass-yellow verging into gold-yellow: its surface is often iridescently tarnished. It occurs in mass, disseminated, superficial, in particular shapes such as stalactitical, clustered, dendritical and reniform: also crystallized in tetrahedrons and the derivative octahedron and dodecahedron. The crystals are

small and very small, and generally difficult to ascertain. The surface of the crystals is smooth and shining, the other varieties are rough and glimmering. The fracture is commonly uneven with coarse or fine grains; the coarse-grained passes into imperfect and small conchoidal, and thence into imperfectly foliated; the fine-grained passes into uneven, even, and flat-conchoidal; the colour of the foliated is gold-yellow, and it has also the strongest lustre. It is brittle, and with difficulty gives a few feeble sparks with the steel: it is easily frangible. Sp. gr. 4. to 4.1.

When exposed to the blowpipe on charcoal it decrepitates, emits a sulphureous vapour, and melts into a black globule, which by continuing the heat acquires the colour and lustre of metallic copper.

It does not appear that the crystallized varieties of this ore have as yet been subjected to analysis, and the proportion of its constituent parts cannot be estimated from the other varieties on account of the iron pyrites which is always blended with them in greater or less quantity. A specimen examined by Lampadius

afforded
41. Copper,
17.1 Iron,
45.1 Sulphur.

103.2

In this analysis the copper and iron were reduced to the metallic state, so that the sulphur (probably for want of sufficient drying) is estimated too high. In general however the produce of copper from this ore does not exceed more than about 20 *per cent.* and in favourable situations it is reckoned worth working when it does not yield more than 5 or 6 *per cent.* A good deal of confusion is observable among mineralogical writers in treating of copper pyrites, some considering it as a peculiar species, while others reckon it only as a variety of iron pyrites holding a variable proportion of copper; and this confusion has been still further increased by assayers and metallurgists, who rank as yellow copper ore every specimen of a yellow colour and metallic lustre, from which a notable proportion of copper can be extracted. It is however necessary to distinguish between copper pyrites, which appears to be a proper double sulphuret of copper and iron, and of which in the crystallized varieties the proportions of the three ingredients are probably permanent; and iron pyrites holding an accidental and variable proportion of copper. Of the former the primitive figure is a regular tetrahedron, its colour

is a golden yellow, it has a brilliant lustre and an uneven granular, or small conchoidal fracture; it is easily scratched by iron pyrites, and its specific gravity does not exceed 4.1. Cupreous iron pyrites on the contrary crystallizes in cubes and their modifications, has little lustre, is of a brassy-yellow colour, an uneven fracture, gives plentiful sparks with steel, and its specific gravity is about 5. The octahedral figure is common to both, as being a modification of the tetrahedron and cube, but the other distinctive characters are permanent. Of the massive amorphous varieties, from which the greater part of the manufactured copper is procured, it is probable that the poorer kinds, as most of the Welch, are chiefly cupreous iron pyrites, while the richer ones of Cornwall are copper pyrites, mixed more or less with mispickel.

Copper pyrites is the most abundant and generally diffused of all the ores of copper. It occurs in veins and beds in primitive, transition, and secondary rocks. In Britain it is found principally in the counties of Cornwall, Derby, Anglesey, and Caernarvon, or in Mainland, one of the Shetland islands.

Sp. VIII. Black Copper. *Kupferschwarze*, Werner. *Cuivre noir*, Brochant.

Its colour is intermediate between bluish and brownish black. It occurs in mass or disseminated or investing. It is composed of dull moderately cohering earthy particles. It is friable, slightly soils the fingers, is meagre to the feel, and heavy.

Before the blowpipe it emits a sulphureous odour, and melts into a slag that colours borax green.

It usually occurs with copper-pyrites, malachite, mountain-green and vitreous copper. It is found in Saxony, Hungary, Silesia, Norway, and Siberia; and at Orme's Head in Caernarvonshire in limestone, accompanied by copper-pyrites, malachite, calcareous spar and pearl-spar.

IV. Family. ARSENICATED COPPER.

Sp. IX. White Copper. *Weiss Kupfererz*, Werner. *Mine de Cuivre blanche*, Brochant.

Its colour is intermediate between silver-white and brassy-yellow. It occurs in mass or disseminated. Internally it has a slight metallic lustre. Its fracture is small and fine-grained uneven. It yields easily to the knife, is brittle and readily frangible. Sp. gr. 4.5.

Before the blowpipe it yields a white smoky with an arsenical odour, and melts into a greyish black slag. According to Henkel it yields 40 per cent. of copper, the remainder being iron, arsenic and sulphur.

It occurs in veins and beds in primitive mountains, and is generally accompanied by copper pyrites and vitreous copper. It is found in the copper mines of Cornwall, Saxony, Hesse, Silesia, Hungary, Siberia, and Chili in South America.

By its colour and arsenical odour when heated, it is distinguished from the sulphurets of copper; and from arsenical pyrites by its inferior specific gravity.

V. Family. CARBONATED COPPER.

Sp. X. Azure Copper or Mountain-blue. *Kupferlazur*, Werner. *Azur de Cuivre*, Brochant. *Cuivre carbonaté bleu*, Haüy.

Of this there are the two following varieties.

Var. 1. Radiated A. C. *Feste K.* Werner. *A. de C. rayonné*, Brochant.

Its principal colour is azure-blue, which passes into Prussian-blue, indigo blue, and rarely to smalt-blue. It occurs sometimes in mass, disseminated or investing, more frequently botryoidal, stalactitic and cellular, but most frequently crystallized. Its primitive form is that of an octohedron with scalene triangular faces; but its usual figures are, an oblique rhomboidal prism, either simple or terminated by two opposite triangular facets and dihedral summits, and an octohedral prism with dihedral summits. The crystals are generally small and very small, aggregated into globular or clustered masses or bundles. The broad faces of the prisms are striated in the direction of their breadth, the narrow faces on the contrary are striated lengthwise, and all the other surfaces are smooth. The crystallized varieties are externally shining, but the rest are dull. Internally it is shining or glistening with a lustre between vitreous and resinous. Its fracture is straight or divergingly radiated, rarely lamellar. The crystals are translucent and semitransparent, the other varieties are opaque or at most translucent on the edges. When pulverized it is of a sky-blue colour. It is soft, brittle and easily frangible. Sp. gr. 3.2 to 3.4.

It is very difficult of fusion before the blowpipe *per se*, but with borax it gives a bright-green glass and a metallic globule.

According to Pelletier it consists of

66	to	70	Copper,
18	—	20	Carbonic acid,
8	—	10	Oxygen,
2	—	—	Water.

Var. 2. Earthy A. C. *Erdige K.* Werner. *A. de C. terreux*, Brochant.

Its colour is smalt-blue. It occurs rarely in mass, generally disseminated or superficial. It

is composed of fine, pulverulent, cohering, dull particles. Its fracture is fine grained earthy, passing occasionally into even and imperfectly conchoidal. It is opaque, slightly stains the fingers, and is easily frangible.

Before the blowpipe it becomes black but does not melt. In borax it dissolves with vehement ebullition forming a green glass.

Azure copper occurs in the newer primitive rocks, but more commonly in floetz mountains. It accompanies other ores of copper, especially malachite, grey copper and copper pyrites. The most beautiful specimens come from the Bannat in Hungary and Siberia. In the Tyrol it is found in sufficient plenty to be manufactured into the pigment called mountain-blue.

Sp. XI. Malachite. *Malachit*, Werner. *Malachite*, Brochant. *Cuivre carbonaté vert*, Haüy.

Of this mineral there are the three following varieties.

Var. 1. Fibrous M. *Fasriger M.* Werner.

Its common colour is grass-green passing into emerald-green and sometimes into dark leek-green. It seldom occurs massive or disseminated, but generally investing, and often crystallized in short capillary needles, disposed commonly in divergent bundles or stars. Externally they are shining, but internally only glistening with a silky lustre. Its fracture is delicate diverging fibrous passing into coarse fibrous. It is opaque or translucent on the edges, the crystals are for the most part translucent. When pulverized it retains its colour, only the tint is somewhat lighter. It is very soft, brittle and easily frangible. Sp. gr. 3.5.

It effervesces with acids, and forms a blue colour with ammonia. Before the blowpipe it blackens and decrepitates, but is infusible *per se*. With borax it melts into a green glass.

Its constituent parts according to Klaproth,

are	58. Copper,
	18. Oxygen,
	12.5 Carbonic acid,
	11.5 Water

100.0

It occurs usually in the newer primitive, and floetz mountains, accompanied by other ores of copper, also by carbonate of lead, calcareous spar, brown spar, and quartz. The finest specimens of this variety of malachite are found in the Siberian and Hungarian mines: it occurs also in Saxony, and various other mining districts in Germany, also in Norway, in the Mainland,

one of the Shetland islands, in Cornwall, Derbyshire, and Ormeshead in Caernarvonshire.

Var. 2. Compact Malachite. *Dichter M.* Werner. *M. compacte* Broch.

Its colour is emerald-green, passing into grass and verdigris green; the same specimen exhibiting different shades: its external surface is commonly overspread with a greenish-white crust. It occurs massive, disseminated, and membranaceous, but most frequently reniform, clustered, mamillated, stalactitic, cellular, or globular. Externally it is rough and dull, or marked by black dendrites. Internally it is, according to the kind of fracture, either dull, glistening or shining. Its fracture is conchoidal or fine granular uneven, or minutely fibrous. It generally occurs in thin lamellar concentric distinct concretions, curved in the same direction as the surface, each of which has generally a different shade of colour, thus giving to the whole a somewhat banded appearance. It is opaque, soft, brittle, and easily frangible. Sp. gr. 3.5 to 3.6.

Its chemical characters and component parts are precisely similar to those of the preceding variety, with which it also agrees in its geognostic and geographical situation. In England it occurs at the Lands-end and other places in Cornwall, also both mamillated and disseminated in red ochery clay, accompanied by copper pyrites, in secondary limestone, at Llanymynech, Montgomeryshire.

Compact Malachite, on account of its fine emerald colour, its variable satiny tissue and lustre, and the high polish that it is capable of receiving, is an extremely ornamental substance, and much sought after on this account. The largest and finest specimen that is known was procured in Siberia, and graced the cabinet of Count Lanskoi at Petersburg, after whose death it passed into the collection of Dr. Guthrie, where it probably still remains. It is a plate about 35 inches long, 18 broad, and above 2 in thickness, and is valued at 800 pounds sterling.

Var. 3. Earthy Malachite. *Kupfergrün* Werner. *Vert de Cuivre* Broch.

Its principal colour is verdegris-green, passing sometimes into emerald-green or sky-blue. It occurs in mass, disseminated, or investing. Internally it is shining, passing into glistening, with a resinous lustre. Its fracture is small conchoidal. It is translucent and semitransparent; is soft and easily frangible.

Its chief chemical character is that of giving little or no effervescence when dissolved in acids.

It has not been analysed. It is found in similar situations with the other varieties of malachite, but is of much rarer occurrence.

Sp. XII. Emerald Copper. *Kupfer-Schmaragd* Werner. *Diopside* Haüy.

Its colour is emerald-green. It occurs crystallized in lengthened dodecahedrons, its primitive form being that of an obtuse rhomboid. It is shining both externally and internally, and has a vitreous lustre. It is translucent, passing to semitransparent; scratches glass feebly and with difficulty; is brittle. Sp. gr. 3.3.

Before the blowpipe it becomes of a chestnut-brown colour, and communicates to the flame a greenish-yellow tinge; it is infusible *per se*. With borax it gives a bead of copper. According to the analysis of Vauquelin, it consists of

Oxyd of copper	25.57
Carbonat of lime	42.85
Silex	28.57

96.99

It has hitherto been found only in Daouria, on the Russian and Chinese frontiers, in a vein accompanied by malachite.

VI. Family. ARSENIAT OF COPPER.

Sp. XIII. Octohedral Arseniat of Copper. *Oktaedrisches Olivenerz* Karsten.

Its usual colour is deep sky-blue, passing into Prussian-blue; it is also found of a bright grass-green, passing into apple-green, greenish-white, and bluish-white. It occurs in obtuse octohedrons, formed by two tetrahedral pyramids with isosceles triangular planes, united base to base. The four planes however seldom terminate in one point, hence the apex is lengthened to a ridge, and the base, instead of being a parallelogram, approaches near to a square. The surfaces are shining and smooth, or striated parallel to their edges. The crystals are implanted in cavities; they have a shining vitreous lustre and a lamellar fracture, are semitransparent, sometimes transparent. Their hardness is inferior to that of fluor spar. Sp. gr. 2.88.

Its constituent parts, according to Chenevix, are

49 Oxyd of copper
14 Arsenic acid
35 Water

98

It is found in Huel-Gorland mine in Cornwall, in veins accompanied by vitreous copper, copper pyrites, arsenical pyrites, and iron ochre.

Sp. XIV. Hexahedral Arseniat of Copper. *Blattriges Olivenerz* Karsten.

Its colour is deep emerald-green, passing to

verdegris-green. It occurs crystallized in thin hexagonal tables. The broad planes are smooth and brilliant, with a metallic lustre. It is translucent, softer than calcareous spar. Sp. gr. 2.54.

When placed on hot coals it decrepitates strongly; its component parts, according to Chenevix, are

58 Oxyd of copper
21 Arsenic acid
21 Water

100

It occurs in the same mine as the preceding species, and is principally accompanied by ruby copper.

Sp. XV. Prismatic Arseniat of Copper. *Prismatisches Olivenerz* Karsten.

Its colour is brownish, or dark bottle-green, verging sometimes to yellowish, in which case it generally reflects the light of a golden tint, when capillary it is of a lighter and brighter colour. It occurs crystallized in an irregular acute octohedron with a rectangular base (which is its primitive form), or in a long rhomboidal or flattened hexahedral prism with dihedral summits, or capillary, either in very lengthened octohedrons or indeterminate. Sometimes the crystals are regular at one extremity, and terminate in capillary brushes at the other. The crystals are small, and are accumulated laterally or implanted. It has a considerable lustre between vitreous and resinous; is translucent, passing to transparent; is harder than fluor, but will not scratch glass. Sp. gr. 4.28.

It passes into the two following varieties.

1. Amianthiform.

Its colour varies from bluish-green to grass-green, brown-green, golden-brown, golden-yellow, straw colour, and white. It occurs in extremely minute parallel or diverging flexible fibres, or thin dusty flexible laminae, with more or less of a fatty lustre.

2. Hematitiform.

Its colour is brownish or whitish-yellow. It occurs in flat or mamillated layers either smooth or covered with little rough crystalline points. Its texture is fibrous, but very compact, resembling wood tin.

This species with the Capillary and Hematitiform varieties has been analysed by Mr. Chenevix, with the following result.

	Prismatic.	Capillary.	Hematitiform.
Oxyd of copper	60.	51	50
Arsenic acid	39.7	29	29
Water	0	18	21
	99.7	98	100

232

It is found in Huel Gorland mine in Cornwall.

Sp. XVI. Trihedral Arseniat of Copper.

Its colour is deep bluish-green, passing to black when in a state of decomposition. It occurs crystallized, in a trihedral prism, whose bases are equilateral triangles (which is its primitive form), sometimes one of the edges of the prism is replaced by a plane parallel to the adjacent ones, forming a tetrahedral prism; sometimes the plane that replaces the edge of the prism is considerably inclined so as to diminish and even obliterate one of the bases, thus forming a wedge-shaped figure with scalene triangular sides. It also occurs in tetrahedral and hexahedral prisms, in very acute rhomboids, and irregular octohedrons; also capillary and mamillated like the preceding species. The crystals are small and very small, when unaltered are transparent but become opaque by decomposition. It is shining, scratches calcareous spar, though with difficulty. Sp. gr. 4.28. Its component parts, according to Chenevix, are

Oxyd of copper	54
Arsenic acid	30
Water	16

100

Sp. XVII. Martial Arseniat of Copper.

Its colour is bright sky-blue. It occurs crystallized in a compressed rhomboidal tetrahedron, terminated at each extremity by a four-sided pyramid, the faces of which are scalene triangles. The prism is sometimes hexahedral, on account of the obtuse edges of the rhomboid being replaced by secondary planes; or octohedral when all the four edges are replaced. The crystals are very small, and are generally grouped together in small spheres. It is shining, transparent, somewhat harder than calcareous spar. Sp. gr. 3.4.

It is composed, according to Chenevix, of

Oxyd of copper	22.5
iron	27.5
Arsenic acid	33.5
Water	12.
Silex	3

98.5

It occurs in Muttrel mine, adjoining to Huel Gorland, accompanied by the same substances as the preceding species.

VII. Family. PHOSPHAT OF COPPER.

Sp. XVIII. Phosphat of Copper.

Its colour externally is greyish-black, inter-

nally between emerald and verdegris-green. It occurs in mass, disseminated, and crystallized in rhomboids, with convex lateral planes. The crystals are small and very small, their surface is drusy, and shining with a high vitreous lustre. Internally it is glittering with a silky lustre. Its fracture is delicate and diverging fibrous. It is opaque, and moderately hard. It consists, according to Klaproth, of

68.13 Oxyd of copper

30.95 Phosphoric acid

99.08

It has hitherto been found only at Firneberg in Cologne, in white drusy quartz. It was formerly mistaken for a variety of malachite.

VIII. Family. MURIAT OF COPPER.

Sp. XIX. Sandy Copper. *Saltzkupfererz* Werner.

Its colour is emerald-green, passing into leek and olive-green. It occurs massive, disseminated, and crystallized in extremely minute six or four-sided prisms. The surface of the crystals is smooth and brilliant, and their fracture lamellar. The massive variety is opaque, the crystals are transparent. It occurs in coarse and small granular distinct concretions. It is soft and easily frangible. Sp. gr. 4.43.

Before the blowpipe on charcoal it tinges the flame of a bright green and blue colour, and a metallic bead remains behind. It is soluble in nitrous acid without effervescence, and almost entirely in ammonia. The following are its constituent parts according to Proust and Klaproth,

Proust		Klaproth
From Peru	Chili	Chili
76.595	70.482	73 Oxyd of copper
10.638	11.446	10.1 Muriatic acid
12.767	18.072	16.9 Water
99.99	100.	100.0

It is found loose in the bed of a river at Remolinos in Chili, and elsewhere, though rarely, in Spanish South America.

Reduction of the Ores.

The reduction of copper ores in the large way is on the whole a very simple business, being little else than a succession of roasting and reducing processes of the simplest kind, till the metal acquires the desired degree of malleability and purity. It is to be observed that both arsenic and sulphur adhere to copper with great

obstinacy, even long after it has assumed the appearance of a pure regulus, and even in very small proportion they make the metal brittle, hard, and difficult to work.

There are scarcely two works in which precisely the same order is observed in the different reducing processes (supposing the quality of the ore to be the same) and as the manufacturer is generally satisfied with that which has been long established and is attended with ordinary success, he seldom enquires whether the labour may be shortened or the expence diminished.

The sulphuret of copper which is obtained in such vast quantities at the Parys mine in Anglesea, is wrought into rough copper in the following manner. The ore is dug up in large pieces (being mostly obtained by blasting) and is first broken into smallish lumps by the hammer, chiefly by women and children, and put into a kiln from which proceed flues that open into a very long close pent-house gallery to collect the sulphur. The kiln is covered close, and a little fire is applied to the mass of ore in different places, whereby the whole is gradually kindled. The sulphur then rises in vapour to the top of the kiln, and thence through the flue into the long gallery, where it slowly condenses, and is afterwards brushed out and further prepared for sale. The mass of ore when once kindled continues to burn of itself with a smouldering heat for about six months, during which time the sulphur-chamber is cleared out four times, after which the ore is sufficiently roasted. The old sulphur-chambers are on a level with the kilns and of the same length and height, or in fact they are a prolongation of the kilns: but the more modern and improved chambers are like lime-kilns, the ore being at the bottom, and the sulphur subliming at the top, with a contrivance to take out the roasted ore, and thus to keep up a perpetual fire.

The richest part of the roasted ore is exported without further preparation, but the poorest part is smelted on the spot. It still contains a vast quantity of sulphur and other impurities. The smelting houses are a range of large reverberatory furnaces, thirty-one of which are under the same roof, ranged side by side in a single long row. They are all air furnaces, the chimneys of which are 41 feet high, which causes a most powerful draught through them. The fuel is coal, which is burned on a grate at the anterior part of the furnace, and the flame in drawing up the chimney passes over the bed of the reverberatory, into which is put 12 cwt. of the roasted ore, previously mixed with a small

portion of coal dust. The ore is here melted and reduced into a very impure regulus, and when sufficiently fused it is drawn off through a plug-hole into earthen moulds. A single charge of the furnace, or 12 cwt. yields $\frac{1}{2}$ a cwt. of rough copper, which by further purification affords about 50 per cent. of pure malleable metal. The furnaces work off a single charge about every five hours.

The copper furnaces in Cornwall are also of the reverberatory kind. The ore when drawn up from the mine is first broken into pieces no bigger than a hazel-nut, which operation is called *cobbing*, and the better sort is picked out by hand. The reduction begins by the process of roasting in large reverberatory furnaces 14 feet by 16, the bottom or bed of which is made of fire-bricks and covered to the thickness of about 2 feet with silicious sand, which runs together by the heat into a semi-vitrified mass. The chimney is from 40 to 50 feet high, which causes such a powerful draught that the arsenic and sulphur separated during the roasting pass almost entirely through the chimney into the open air, none of it being collected as at Anglesea. The ore is spread over the bottom of the furnace about a foot thick, being thrown in through a kind of funnel or hopper just above. The fuel is Welsh coal, which, as usual, is burnt at the anterior part of the furnace, and its flame draws over the surface of the ore in its passage to the chimney. In this furnace, which is called the calcining furnace, and is the largest of all, the ore is roasted without addition with a dull red heat for 12 hours, and is frequently in that time stirred with a long iron rake, introduced through a hole at the further end of the reverberatory, to expose fresh surfaces to the action of the flame. The ore is not melted here, but when roasted sufficiently, it is carried to another furnace exactly similar to the former, but smaller, that is, about 9 feet by 6, and here it receives a fusing heat, but still without any addition, except that when the slag does not rise freely, a little calcareous sand is thrown in. At the end of every four hours the slag is raked out; it is then of the consistence of soft dough and is laded into oblong moulds, and a little water is sprinkled upon it to make it sink down, after which the moulds are quite filled with it, and when cold it makes hard solid blocks of slag about 14 inches long and 12 deep and broad, which are used for building. After the slag is raked off, a fresh charge of calcined ore is let down into the reverberatory, and the copper is tapped off by a hole in the side of the

furnace, which before the fusion had been stopped up with a shovel full of wet clay mixed with about a fourth of new coal, which prevents the clay from hardening too much, so that the hole may readily be opened by an iron pick.

The rough copper as it runs from the furnace is conveyed by a gutter into a large kind of bucket suspended by chains in a well through which a stream of water is passing, and here, in falling into the water, the metal is granulated, which takes place without explosion or danger, and it is then drawn out by raising the bucket.

The copper is still however extremely impure, though apparently in the metallic state, being grey and perfectly brittle, and still mixed with arsenic and sulphur, to separate which is the work of several subsequent processes. It is then remelted and granulated twice more or oftener, each time throwing up a slag in the furnace, which is removed before the plug-hole is tapped; but as this slag contains some copper, it is not cast into moulds as the first, but worked over and over again with the fresh charges of calcined ore. The number of fusions and granulations is entirely determined by the nature of the ore. The granulated mass is then melted and cast into pigs, which have a blistered appearance on the surface, and are broken up and roasted for one or two days in a low red heat, and again melted and roasted as before for several times till the metal is considerably purer, and at last is cast in oblong iron moulds about 14 inches in length, when it is removed to the *Refining Furnace*. Here it is again melted with the addition of a little charcoal, till it is brought to a sufficient purity to bear the hammer, and is now good saleable copper.

It is observable that in the former process when the crude and brittle metal is cast in sand in the form of large pigs or ingots, the best part of the copper rises to the surface, and when cold may be knocked off with a hammer, forming a brittle crust about three-quarters of an inch thick, of a grey colour and a steel-like fracture.

Thus by a series of successive calcinations and fusions in the simplest manner possible, the common copper ores are freed from arsenic, sulphur and earthy matters, and gradually brought to the state of malleable copper. Where a variety of ores from different places and of different species are brought to the same smelting-house (which is the case in many of the houses at Swansea and different parts of the Bristol coast) much technical judgment is exercised in sorting

the ores and distributing the charges for the furnace in such a manner that the more fusible will assist the reduction of the refractory, and the poorer will be made more worth working by the addition of a portion of the richer ores, and the like.

The subsequent operations whereby the ingots or pigs of malleable copper are formed into sheet copper, wire, nails, bolts, cauldrons, and an infinite variety of manufactured articles, do not come within the province of pure chemistry: it may be sufficient to observe that the hammering renders the metal much more uniform, close, and ductile, but this requires to be frequently alternated with annealing at a full red heat, to prevent the metal from cracking under the powerful pressure to which it is exposed. Immediately after the last annealing, the copper plates are quenched in urine, which somewhat hardens the surface, and gives it that redness which is considered by the merchant as one mark of the purity of the metal.

In the reduction of the copper ores of Neufol in Hungary, lead is used in the refining part of the process^b in the following manner: the rough copper is spread on the bed of a furnace, and when it has been six hours in fusion, some lead, in the proportion of from 6 to 8 per cent. of the copper, is thrown in, which immediately begins to vitrify and to form a thick scoria along with the impurities of the copper, which is skimmed off successively till the whole is exhausted and the copper remains fine and clear. This process lasts from 10 to 12 hours, with 50 quintals of raw copper. The scoriæ retain a portion of copper, which makes it answer to work them again.

The power which the vitrified oxyd of lead has to scorify all metals, except gold, silver and platina, is amply shewn in the process of *Assaying*, and hence it must happen that in refining, some of the copper becomes oxidated together with the lead; but the same process of assaying shews that copper requires a large portion of lead for this purpose, and therefore the latter metal in so small a proportion as 6 to 8 per cent. is probably a most useful addition where not too expensive. For of all the common imperfect metals, copper is that which scorifies and oxidates with most difficulty when in fusion, and therefore the same method, with some little variety, may be practised to separate lead and tin (for example) from copper, as any or all of these metals from silver or gold, care being taken in the former case not to carry the scori-

fication beyond what is necessary to separate the more easily oxidable metals from the copper which then remains in the metallic state. This will be further noticed in the succeeding article of *Alloys of Copper*, and the purification of bell-metal. After the greater part of the lead has been worked off as often as is judged necessary, the remaining copper must be kept for a while longer in fusion, to throw up the last portions of lead that may adhere. In assaying gold or silver the total expulsion of the lead is known by the fine metal becoming at once brilliant on the surface, but in refining copper this appearance can never take place, as the copper itself always forms a thin oxyd on its melted surface; and therefore, to judge whether it is pure, the workman dips a polished iron rod in the melted mass, and draws out a portion of copper adhering to it, which, if pure, immediately falls off when the rod is dipped in water. The colour of the scoria is also another test. While the copper remains impure and alloyed with iron, sulphur, &c. the vitrified oxyd on the surface is black or of a dirty brown, but the scoria of pure copper is red, and also is readily separated from the iron when cold, leaving no stain behind.

The plates of fine red copper, called *Rosette Copper*, are made in the following way.^c When the refined copper is found by the way just mentioned to be sufficiently pure, the surface of the melted metal is well scummed and suffered to cool till it is ready to fix, at which time a workman brushes it over with a wet broom, which immediately fixes the surface and causes a thin plate to separate from the still fluid metal below. This plate is taken off and thrown into water, where it takes a high red colour, and the same process of wetting the surface is repeated with the remaining fluid metal successively, till the whole is reduced to these thin irregular plates.

A considerable quantity of copper is obtained from the springs of native sulphat of copper or blue vitriol, which are found in most copper mines or flow from hills containing this metal. To obtain it, the vitriol water is pumped up into large square open pits, two or three feet deep, made with rammed clay, into which is thrown a quantity of refuse iron of any kind, and suffered to remain for a considerable time, during which the iron is dissolved, displacing by superior affinity the copper which is precipitated in the form of a brown mud. When the water is thus exhausted of its copper, the pits are

raked out, and the oxyd collected from them is simply dried in the sun. It is then fit for reduction in the reverberatory furnaces in the usual manner. This is by far the richest material employed, for, though containing some clay and iron mixed with the copper, it yields on an average full 50 per cent. of pure metal, and therefore it is seldom smelted by itself, but mixed with the poorer ores, some of which contain no more than 5 per cent. of metal.

Many of the finest copper ores contain so much silver as to make it worth while to extract this last metal by a separate operation, which will be described under the article *Silver*. In all the different roastings and reductions necessary to bring the copper to purity, the silver remains united with it.

Analysis of Copper Ores.

The number of the analyses made of the different species of copper ores is so immense, that a selection only of the most approved can here be given; and a few general rules may be premised, which will simplify the subject.

The analysis of ores is usually conducted in one of two distinct ways, the *dry* and the *moist*, each of which has its peculiar advantages and defects.

In the dry way, the ores when they contain sulphur or arsenic (which is the case with the greater number) are first *roasted* in order to dissipate the greater part of these mineralizing substances. For this purpose, in analysis in the small way, they are mixed with about their bulk of charcoal powder (or better with fine saw-dust) and exposed to a low red heat on a flat tile or muffle, or any other convenient apparatus on which they can be thinly spread. The sulphur or arsenic soon begins to rise in fumes which should be hastened by frequent stirring, keeping the heat just below the point at which the ore would run and clot together, to prevent which is one considerable use of the charcoal or saw-dust.

When no more fumes sensibly arise, and the charcoal is entirely burnt off, the part of the ore that remains now consists of the metallic portion in the state of an oxyd, still mixed however with a quantity of sulphur or arsenic, which mere roasting will not separate, and of all the earthy matrix that may have been originally contained.

The ore is then fitted for the second process, which is that of *reduction* of the metallic oxyds to the reguline state. All that is essentially necessary to reduction is, to expose the oxyd to a

^c Macquer, Chem. Dict.

high heat in contact with charcoal or carbonaceous matter of any kind, and secluded from the contact of air. In reducing the metals volatile in heat, such as zinc or antimony, this reduction requires somewhat of a different apparatus from the fixed metals, to which chiefly the present observations apply. It has been a constant custom with chemists in almost all cases (till of late years) to add to the ore in reduction, not only a due quantity of carbonaceous matter, but also to mix it with a large proportion (seldom less than thrice its weight) of some alkaline or easily vitrifiable matter to serve as a *flux* to promote the fusion of all the heterogeneous contents of the ore, and to afford a thin-flowing medium, through which the globules of reduced metal can readily fall by their superior gravity, and at last be collected in a single mass or button at the bottom of the crucible.

In all the common processes of reduction, therefore, which are usually given, the additions to the ore are of two kinds, the purpose of which should be well distinguished, namely, the carbonaceous matter, which is essential to the difoxygenation of the metallic oxyd, and the saline or fusible flux, the use of which is often highly convenient and even necessary, but also often needless or even detrimental. The invariable fault of saline fluxes as generally applied, is, that they always dissolve a portion of the metallic oxyd before it has time to pass to the metallic state, and retain it permanently, thus robbing the metallic button of a part of what otherwise would unite with it: and hence it almost invariably happens that common assays made in the dry way with saline fluxes return a less proportion of metal than the ore really contains. Nor is this loss trifling in many instances, since the accurate Klaproth found a difference of 9 per cent. between the yield of copper from a certain ore assayed in the dry way, and the same ore treated in a different manner, in the moist way. As a proof of the solution of a part of the metallic oxyd in the saline flux, it may be added that the scoria, or flux after melting, is always found deeply coloured with that precise tint which would be given, as in the common preparation of coloured glasses, by the designed admixture of the oxyd of the metal used. Thus the scoriæ of reduced cobalt ore are of a deep blue; of fine copper, green or brown according to circumstances; of iron grass-green, and the like. The loss of metal is still greater when the ore retains a portion of sul-

phur, which last uniting with the alkali, acts with still more power on the metallic oxyds.

As naked alkaline fluxes are peculiarly liable to this inconvenience, some eminent docimastic chemists employ with considerable success fluxes of equal power, but with less disposition to dissolve the metallic oxyds. Of this kind are very fusible glasses made of much alkali and flux without litharge or other metallic admixture, fluor spar, lime, and above all, borax. This last produces a thinner fusion of vitrifying mixtures than an equal quantity of any other substance whatever, and hence a smaller dose of this than of the naked alkalies, will answer all the purposes of a flux, and of course the loss by solution of the metallic oxyd is much less.

A reduction of the sulphuretted ores is sometimes conveniently effected by a single operation which gives a button of metal of considerable purity. The roasting, which is always a tedious operation, is saved by mixing the ore with two or three times its weight of nitre, and projecting it into a hot crucible. The mixture dephlagrates on reaching the crucible, the sulphur is burnt and converted to sulphuric acid which unites with the potash of the decomposed nitre, and the metal, now freed from the sulphur, becomes fully oxygenated by the nitric acid and ready for reduction. This is effected by throwing in a reducing flux of tartar and pitch or any similar matter, and applying a strong heat for the requisite time.

It appears, however, that though nitre is often a good and expeditious method of freeing ores from their sulphur, it is better not to perform the whole reduction in a single operation, but first to separate the metallic oxyd after dephlagration (which may be done by washing) and then to reduce it by a proper flux.

The reduction of the pure oxyds or carbonated oxyds of copper, whether natural or artificial, is effected without loss, and in by far the best method, simply by heating intensely in contact with charcoal in a covered crucible. This is in fact a very close imitation of the method of reduction in the large way of the roasted copper ores, only as these latter still contain sulphur, arsenic, iron, and other foreign matters, the process requires to be repeated many times before the copper is in a pure malleable state, in each of which, the impurities separate in the form of a thick pasty scum, as already described, under the article of reduction in the large way.

In small experiments, where saline fluxes are

used, these impurities dissolve in the flux (which is one of the great uses of these substances) and one or at most two operations, will suffice.

When copper is pure (that is, of a saleable purity, for it is very rarely found absolutely pure) it is soft, malleable, and of a beautiful brilliant yellow-red where recently cut or filed. On the contrary, when containing sulphur, arsenic, or iron, it is black, dense, sonorous, brittle, and more of a vitreous than a truly metallic appearance. In this state it is called *copper-matt*, or *black copper* by metallurgists. Subsequent melting in contact with air, or with fluxes, removes these impurities, and if the operation be judiciously performed, the loss sustained by the matt, in being converted into pure copper is principally that of the impurities; for it is a valuable property of this metal to be much less easily oxidated, scorified, and dissolved by sulphurets, than any of the metals with which it is usually found mixed, and particularly than iron.

After all, however, the analysis of copper ores in the dry way can only give an approximation to accuracy in the result, except in the treatment of the pure native oxyds or carbonats, which are indeed among the most valuable ores, but are those which the seldomest come under the notice of the practical metallurgist.

The analysis of copper ores in the moist way is performed in a tolerably uniform manner, the ore being first treated with an acid which dissolves all the metallic part, leaving the sulphur and filix; after which the different metals are separately precipitated from the solution, either in the metallic state, or in certain known forms of combination, from which the metallic portion can be accurately inferred.

The particular steps of many of these analyses will be presently given; the general mode of separating copper from the metals with which it is alloyed is as follows: *from silver*, by adding to the nitrous solution of the mixed metals muriat of soda, which separates the silver, as luna cornea, and leaves the copper:—*from lead*, by adding to the solution sulphat of soda, which precipitates an insoluble sulphat of lead, and leaves the copper:—*from antimony*, by digesting the mixed oxyds of copper and antimony with nitric acid, which dissolves the copper and leaves the antimony:—*from iron*, by supersaturating the mixed solution with ammonia, which redissolves the copper and leaves the oxyd of iron; or else by immersing a piece of polished iron in the solution, which will separate the copper and leave the iron in solution, (a precaution to be observed here, however, will

be presently mentioned):—*from tin*, by immersing a piece of metallic tin in the solution, which will precipitate the copper only:—*from arsenic*, by dissolving in nitrous acid and adding acetite or nitrat of lead which will separate the arsenic in the form of an insoluble arseniat of lead, and leave the copper. If an excess of lead remain, add sulphat of soda, as above mentioned:—*from Nickel* in the following way: when this metal is found it is generally in conjunction with iron; and ammonia, which precipitates all the three metals from their acid solution, redissolves, when in excess, both the nickel and copper; but to obtain the copper singly, again supersaturate with muriatic acid, and immerse a piece of iron, which will separate the copper, and leave the nickel dissolved.

Copper is obtained separate, in wet analysis, in three states, in each of which the weight may be taken, either in the metallic state, or as the green carbonat, or as the black oxyd. If a piece of polished iron is immersed in an acid solution of copper it is almost instantly covered with a brilliant coating of metallic copper, owing to an exchange having taken place, a portion of the iron being dissolved, and separating an equivalent quantity of copper from the solution. As this proceeds, the precipitate of metallic copper increases, and incrusts the remaining iron, forming a bundle of ragged filaments which the slightest force will detach if the solution is sufficiently diluted. At last the solution contains only iron, and the whole of the copper is thus obtained in the metallic state, which only requires washing and drying. This precipitation is much assisted by boiling for a short time, especially at last, without which indeed the last portions of copper will hardly separate. The solution when purely cupreous is of a fine azure blue, but when converted to a solution of iron becomes green. It should be remembered, however, that for a perfect separation of copper from iron by this method, the solution should be in the sulphuric or muriatic acids and not the nitrous, for though iron will equally displace copper from the nitrous as from the other acids, the nitrat of iron is itself largely decomposed by mere heat or exposure to air, and lets fall a fully oxidated iron, which in this case mixes with the fine filaments of the reduced copper, and vitiates the result of the analysis. When, therefore, it has been necessary to employ this acid in the previous part of the analysis, the metallic contents should either be first precipitated by an alkali and redissolved in muriatic acid, or the

nitric solution should be evaporated to dryness, redissolved in muriatic acid, and again dried and moderately heated for some time, whereby the nitrous acid is expelled, and a metallic muriat remains for further treatment.

Instead of iron, tin or especially zinc may be used as the precipitant of the copper from its solution: these act more speedily and with equal certainty. With either of these two, as their muriat is colourless, the total absence of the copper (provided iron or nickel is not at the same time present) is seen by the solution becoming entirely void of colour.

Mr. Chenevix has also remarked^d a singular circumstance in these precipitations, which is, that if the acid, (particularly the muriatic) be in excess, a quantity of hydrogen is disengaged, as occurs in the common solutions of these metals, and the whole of the copper is separated in a very short time. With muriat of copper, zinc, and an excess of muriatic acid, the separation is surprisingly rapid, and much advantage may be made of this fact in the analysis of copper ores.

It is to be observed, however, that zinc will precipitate iron as well as copper from its solutions, but scarcely any of the iron will separate till all the copper is precipitated. Thus if zinc is added to a mixed solution of sulphat or muriat of iron and copper, the first precipitate is obviously copper and little else, but at the time when the solution begins scarcely to turn blue with ammonia, a black powdery oxyd of iron mixes with the copper. Even if no iron be contained in the cupreous solution, if there is an excess of acid, and *common* zinc (which always contains iron) be used, some of it will still appear in the precipitate; the excess of acid appearing first to dissolve both the zinc and iron, and the latter being again separated by the zinc that remains. On this account, perhaps, iron is a more accurate reagent than zinc in these analyses. As the muriat of copper seems to yield its metal with more ease than the sulphat, it might perhaps be of use previously to convert the sulphat into a muriat by the addition of common salt. The colour immediately changes to green, which is a proof of this change of the cupreous salt.

The report of the assay will probably be still more accurate, if the precipitated copper, after being washed and dried, instead of being immediately weighed, is put into a small crucible, moistened with a drop or two of oil, covered

with borax, and strongly heated for a few minutes whereby it becomes a solid button of good malleable copper.

The second state is that of the green carbonat. If carbonated potash or soda be added to a solution of copper, a green precipitate is formed, which, when washed and dried at the heat of boiling water, gives an uniform green powder. Its exact nature will be mentioned when describing the carbonat of copper, but it may be here added, that 180 parts of this carbonat are equivalent to 100 of metallic copper, and may be reckoned as such in all analyses. But as the pure fixed alkalies give a precipitate which may occasionally be confounded with this carbonat, this method of estimation is not quite so good as the following.

The third state in which copper may be estimated is that of the black oxyd. If the green carbonat last mentioned (and it need not be washed with particular care nor dried) be boiled for a few moments in caustic potash, it at once shrinks considerably and becomes a deep brownish black fine powder, which is a pure oxyd of copper in its highest state of oxygenation. One hundred parts of this oxyd, well washed and dried in a low red heat for a minute or two, invariably contain eighty parts of pure metallic copper. The ammoniated copper gives the same oxyd when boiled with potash.

It is also produced at once by adding potash or soda to the acid solutions of copper, and *boiling for a minute or two* (which last is an essential circumstance) and this is a better method of proceeding in analysis, since an excess of carbonated alkali will redissolve a part of the green carbonat, and vitiate the analysis, whereas no such effect is to be feared from an excess of the pure fixed alkalies at a boiling heat.

The leading steps of the actual analyses of some of the principal copper ores by the most accurate chemists may now be given in a few words, as a specimen of the mode of proceeding in different cases.

Of the ores composed chiefly of copper, iron, and sulphur.

The vitreous copper ore was thus analysed by Klaproth.^e

To 200 grains of the powdered ore muriatic acid was added in a boiling heat, which had no immediate effect, but on dropping in a little nitrous acid, solution began with violent disengagement of nitrous gas. When every thing soluble was taken up, the solution consisted of a clear

^d Phil. Trans. for 1801, p. 211.

^e Essays, vol. i.

green liquor on which the sulphur was floating. The insoluble part amounted to $38\frac{1}{2}$ grains, 37 of which were dissipated by calcination and were sulphur, leaving $1\frac{1}{2}$ of filix behind. The solution was divided into two parts, one to ascertain the copper, the other the iron.

Into the former a bar of polished iron was immersed, and by rest $78\frac{1}{2}$ grains of copper were precipitated. The other half was supersaturated with ammonia, which first precipitated both the iron and copper, and then redissolved only the copper, leaving 3 grains of oxyd of iron, equal to $2\frac{1}{2}$ of metallic iron. Hence the iron, copper, filix, and sulphur were separately estimated. The copper is presumed to be in the metallic state in this ore on account of the violent evolution of nitrous gas. It is to be observed that by a previous trial the ore was found by the tests before described to be free from silver and lead, that is by giving no precipitate either with muriat of soda, of sulphat of soda.

The variegated copper ore was assayed by the same eminent chemist in nearly the same manner. On account of its colour and its making much less effervescence with nitric acid, a portion of oxygen is supposed to be combined with it.

The same was assayed in the dry way by being mixed with one-fourth of its weight of charcoal and roasted, then mixed with a fourth of colophony or rosin, and thrice its weight of black flux, and well fused. The result was a button of copper, but 10 per cent. less than the quantity of metal obtained in the moist way.

The yellow hæmatitic copper ore and the grey vitreous ore from Cornwall, were analysed by Mr. Chenevix[†] nearly in the same manner as above described, only the whole solution was supersaturated with ammonia, and the copper separated from the ammoniated solution by boiling with potash, in the form of the black oxyd, of which 100 parts were estimated as equal to 80 of copper.

Ore of Silver, Copper, Iron, Antimony and Sulphur.

Klaproth's analysis of the Fahlerz[‡] deserves a short notice on account of the skill with which it was managed.

The ore was first digested repeatedly with nitric acid, which dissolved somewhat less than half. From the solution muriat of soda separated some silver, and it was then tried for lead by sulphat of soda. It was next supersaturated

with ammonia whereby a precipitate was left, which by subsequent treatment was found to consist of iron with a little alumine and filix. The ammoniated solution which now only contained copper, was supersaturated with sulphuric acid, and the copper separated by iron.

The first residue untouched by the nitric acid (amounting to more than half the ore) was then digested with muriatic acid, which dissolved nearly half, leaving a residue which by subsequent fusion with alkali was found to be filix, still holding a minute portion of silver. The muriatic solution was evaporated, during which it deposited a few small crystals of muriat of silver, after which water was added, which separated an abundant white oxyd, which was found by various trials to be antimony.

Oxyds and Carbonated Oxyds of Copper.

The purest native oxyd of copper is the red octohedral ore from Cornwall. This appears to consist of nothing but copper and oxygen, but, according to Mr. Chenevix,^h the copper here exists in a less state of oxygenation than in any other known ore of this metal.

One hundred parts were totally dissolved in nitric acid with copious effervescence of nitrous gas. The pure blue solution was evaporated to dryness, muriatic acid was added, and a second time evaporated to expel the remaining nitric acid, and convert the salt to a muriat. This latter diluted with water gave up 88.5 of copper to a plate of iron immersed. Hence it is found to consist of 88.5 of copper and 11.5 of oxygen. The particulars of this analysis will be further noticed when describing the oxyds and muriat of copper.

The pure carbonated oxyds of copper consist of carbonic acid, oxygen, copper and water. With almost any acid they effervesce strongly, and give out their carbonic acid.

Fontana was the first who clearly shewed the presence of carbonic acid in these ores. By distilling malachite *per se* in a glass retort, and collecting the products, he obtained some pure water, and a large quantity of gas, which extinguished a candle, precipitated lime-water, and by various tests was found to be carbonic acid.

The Siberian malachite analysed by Klaproth will furnish another example of analysis. A hundred grains calcined in a moderate red heat in a covered crucible lost $29\frac{1}{2}$, which therefore is the quantity of the carbonic acid and water. Another 100 grains were dissolved in dilute sulphuric acid, and lost by effervescence 18

[†] Ph. Transf. vol. 91.

[‡] Essays, vol. 1.

^h Phil. Transf. for 1801.

grains, which, subtracted from the $29\frac{1}{2}$, leaves 11.5 for the water. The sulphuric solution decomposed by metallic zinc gave 58 grains of copper. Another portion of the malachite was dissolved in nitric acid, and the precipitate by ammonia was entirely redissolved by an excess of this alkali, shewing therefore the total absence of iron. Lastly, the quantity of oxygen united with the copper is inferred to be that which must be added to the 58 and $29\frac{1}{2}$ to make up the 100, namely 12.5.

The native carbonat when pure has precisely the same composition as the artificial, as Proust has clearly shewn, and will be presently mentioned.

Arseniat of Copper.

The composition of the different species of this family of copper ores as far as it is hitherto known is extremely simple, the ore when separated from its matrix containing nothing but arsenic acid, oxyd of copper, water, and sometimes a portion of iron. The arsenic acid is best estimated by uniting it by stronger affinity with some other metal where it makes an insoluble salt of a known and invariable composition. Lead is the best fitted for this purpose, so that when the nitrat or acetite of lead is added to arseniat of copper, a soluble nitrat or acetite of copper is formed, together with a white insoluble precipitate of arseniat of lead. By preliminary experiments Klaproth found that 100 grains of solid arsenical acid gave 297 grains of solid arseniat of lead after moderate drying, and hence 100 grains of the arseniat contain 33.66 of arsenic acid.¹

For the analysis, the ore being first dissolved in nitric acid, the solution was accurately neutralized with carbonated potash, and then acetited lead was added till all precipitation ceased, a little of this salt remaining in excess. The precipitate of arseniated lead when washed and dried indicated the proportion of arsenic acid in the ore. The solution now contained acetic and nitric acids, united with oxyd of copper and potash, and a little acetited lead; from which the lead was first separated by sulphat of soda, that precipitated it in the form of an insoluble sulphat, after which a little sulphuric acid was added to engage the copper, and this metal in its turn was separated by polished iron in the usual manner. The copper however is thus obtained in the metallic state, but in the ore it is an oxyd, and therefore one-fourth of the weight of the copper must be added for oxygen, that is (as in the actual analysis) for 40 parts of metallic copper, 50 of the

oxyd of copper must be estimated. It is necessary to neutralize the nitrous solution at first, as the arseniated lead is very soluble in acids, and therefore would not otherwise be properly collected.

Where iron is suspected in the ore, the solution instead of being finally precipitated by polished iron may be decomposed by ammonia, and the copper separated from the iron by an excess of the alkali.

As many acids form a white precipitate with the solutions of lead, the powder in question is proved to be arseniat of lead by digesting with sulphuric acid, which displaces the former acid, and leaves it uncombined in the liquor; and arsenic acid is detected by various methods mentioned under that article, particularly by giving a brick-red precipitate with nitrat of silver, the arsenic acid being first neutralized with soda.

Mr. Chenevix analyses the arseniats of copper in the same general way, but with some variations.

The ore (previously heated moderately to expel and estimate the mere water) is dissolved in dilute nitric acid and nitrat of lead poured in. The solution (containing an excess of acid and therefore holding some of the arseniated lead dissolved) is then evaporated nearly to dryness, and alcohol added to compleat the separation of the arseniat of lead. After which the copper is decomposed by potash, and is obtained in the state of the brown oxyd.

Muriat of Copper.

The composition of this singular ore, found hitherto only in Peru, was ascertained nearly at the same time by Proust, and by Rochfoucault, Beaumé, Fourcroy and Berthollet, a committee nominated for the purpose by the French Academy. The experiments are instructive.

The ore thrown on hot coals burns with a beautiful blue and green flame, whereas malachite, which it most resembles in appearance, gives only a faint green flame. Distilled *per se*, malachite gives no other volatile product than carbonic acid and water; whereas the muriat gives in the same process a quantity of oxygen gas with only a very small proportion of carbonic acid, and a green liquor strongly smelling of muriatic acid and proved to contain copper by giving a fine blue with ammonia. The residue in the retort was a brown oxyd of copper. This when exposed to air turns green, shewing therefore that it is not a simple, but a muriated oxyd. Part of the muriat of copper therefore is volatilized, as it is well known that this salt readily

¹ Klaproth, vol. ii. 148.

rises in distillation. The muriatic acid however is not sufficient in this ore to saturate the oxyd of copper, and hence by simple boiling in water only a small portion is dissolved, which gives luna cornea with nitrat of silver.

This ore was analyzed by Klaproth in the following simple manner, its general contents having been ascertained by the above-mentioned experiments. One hundred grains of the ore were dissolved in nitric acid without heat, during which about $1\frac{1}{2}$ of iron ochre was deposited. It was then diluted and nitrat of silver added to ascertain the quantity of luna cornea. Of this last, $64\frac{1}{2}$ grains were obtained, of which 10 grains were muriatic acid, according to separate experiments by which it appears that 100 grains of silver form 133 of luna cornea, and of the 33 grains additional weight, $12\frac{1}{2}$ are oxygen, and $20\frac{1}{2}$ muriatic acid. The copper was then precipitated as usual by iron, and weighed $57\frac{1}{2}$ grains in the metallic state, equal to 73 of the brown oxyd. Klaproth does not consider the iron however as essential to the ore, and therefore excludes it from the estimate.

Phosphat of Copper.

This rare mineral was analyzed by Klaproth in the following way. It was first dissolved in nitric acid, which made a clear blue solution, leaving untouched 16 parts out of 100, which were quartz. The solution was then just saturated with potash to engage any excess of nitric acid, and acetited lead was then added, which gave a copious white precipitate, and a small excess of the acetite was used to ensure the compleat precipitation. This white insoluble salt from appearance might be either sulphat, or arseniat, or muriat, or phosphat of lead, but it was proved to be the latter by the two following tests: 1st. when fused by the blowpipe, in the moment of cooling it assumed a garnet-like form with shining surfaces, which sudden crystallization is peculiar to phosphat of lead; and 2dly, when digested with dilute sulphuric acid, sulphat of lead was formed, and naked phosphoric acid remained in the liquor, which being neutralized, partly by soda and partly by ammonia, gave the well-known microcosmic salt. The native phosphoric acid was therefore separated from the copper in this analysis, and from 100 grains (exclusive of the quartz) 138 grains of phosphat of lead were formed, the phosphoric acid of which was estimated from other experiments to amount to 30.95 grains. The cupreous solution was then treated with a little sulphat of soda, to separate

the lead from the excess of the acetite remaining; some naked sulphuric acid was then added, and the copper was separated by iron in the metallic state, which (increased in the proportion of 125 to 100), was found equal to 68.13 of oxyd of copper.

The above analyses include almost all the important ores of copper, except those in which it is combined with tin, which will be treated of under that metal. It may be mentioned however that the most accurate way of separating copper from tin appears to be to immerse in a solution of both metals a stick of tin, which will precipitate all the copper, whilst the loss of weight of the immersed tin subtracted from the entire quantity of tin afterwards obtained from the solution, will indicate the quantity of tin belonging to the ore.

To proceed to the properties of pure copper.

COPPER is a metal of a brownish red colour, very ductile, malleable, and tenacious, so as readily to be flattened into thin plates, and to be drawn out into wire of great strength comparatively to its thickness, more so (according to Count Sickingen) even than gold. It breaks with a hackly fracture. When rubbed, it emits a disagreeable smell, and it gives a styptic and nauseous taste. The specific gravity of the purest Swedish copper is 8.895^k, that of the better kinds met with in commerce but of less purity than the former, varies from this weight to about 8.6. The Japanese copper is found by Bergman to be 9.0.

Copper requires for fusion what is commonly called a white heat, which is apparently not more, however, than is required to melt gold or silver. Before it melts, it shews on its surface changeable prismatic colours. When in fusion, or even at a heat somewhat below, if with access of air, it begins to oxidate on the surface forming thin brown scales. These may readily be knocked off when cold, and are then very brittle. This is an imperfect oxyd of copper, formerly called *copper ashes*, *as ustum*, or *cinis æris*, and by repeatedly heating and cooling a bar of this metal, the whole may be thus changed. These scales are found by Proust¹ to consist of about 62 of the black or compleat oxyd, and 38 of copper nearly metallic. Dilute sulphuric acid ascertains this by dissolving (when without heat) only the former part. By separate calcination the whole is reducible into the black oxyd, which weighs one-fourth more than the copper from which it is procured. When intensely heated the oxyd runs into a bright red-brown

^k Hatchett. Phil. Transf. vol. 93.

¹ An. Chim. tom. 32.

glafs. At a heat fomewhat above melting, a blue-green flame hovers on the oxidated furface of the metal, which is ftill more vifible when the oxyd is thrown on the naked coals, and is moft intenfely bright and beautiful when copper wire is burned by a ftong galvanic pile.

The fame colour, with fome variation of fhade, is alfo produced by all the falts of copper when in contact with any burning combuftible, thus they tinge the flame of alcohol very beautifully. The nitrat or muriat fhews this to the beft advantage. The flame of burning copper deposits, though fcantly, a fine greenifh-grey oxyd, and hence it gradually collects as a kind of foot in the chimneys of copper-smelting houfes.

Copper foon rufts in a damp air, and becomes covered with a fine green cruft, which alfo contains carbonic acid. But this fuperficial coating long preferves the reft of the metal beneath, and hence it is the work of a great length of time, and of circumftances very unfavourable to prefervation, to corrode entirely a thick plate of this metal. Water projected on white-hot copper does not oxydate it, as it does iron, and no hydrogen is produced thereby.

Except in one or two rare combinations, copper appears to unite very uniformly with the fame dose of oxygen, forming (when free from water and every other fubftance) a brownifh-black oxyd, of which 20 per cent. or one-fifth, is oxygen, and the remainder is metal. This oxyd, as already mentioned in the analyfis of the ores, is invariably produced by boiling for a very fhort time in potafh any of the precipitates from the cupreous falts by any alkali, pure or carbonated, or the ammoniated folution of copper. The fub-oxyd will be defcribed with the muriat.

Copper or its oxyd is foluble in almoft every acid with more or lefs eafe. Many of thefe falts are of confiderable importance.

Sulphuric acid acts upon copper only when concentrated and with the affiftance of heat. For this purpofe take copper-filings or clippings of thin fhheet copper, put them into a glafs veffel with about twice their weight of sulphuric acid, and heat the mixture. As foon as folution begins, much fuphureous acid gas is given out (which is a very convenient way of procuring this gas), and at laft the whole is diffolved into a dark coloured liquor, except a fmall quantity of black refidue, which is the fuphuret contained more or lefs in all common copper. By dilution with water the liquor becomes of a fine blue.

This folution, by due evaporation and cooling, furnifhes cryftals alfo of the fame colour, and

when regular (which they very feldom are) of a rhomboidal fhape, forming the fuphat of copper, or *blue* or *Roman Vitriol* of the fhops.

Blue vitriol is alfo found native in abundance, partly cryftallized, but generally diffolved in the water of copper mines. Here it is produced by the decomposition of the native copper pyrites in the fame maner that the native fuphat of iron arifes from decomposed iron pyrites.

Sulphuric acid diffolves the oxyds of copper with eafe even in the cold, and when diluted. The green carbonated oxyd is the moft foluble in this acid.

Sulphat of copper has a very ftong ftyptic, fomewhat acid, and naufeous tafte. It is foluble in about four times its weight of water. When dried at a moderate heat, not exceeding that of boiling water, this falt lofes, according to Prouft, about 36 per cent. which is mere water, after which, the refidue, which is a white powdery mafs, is equally again foluble and cryftallizable. But if it is calcined with a ftong heat the acid itfelf is at laft expelled, but without decomposition, (being wholly fuphureous acid, as in the calcination of fuphat of iron) and a further lofs of 33 on the 100 of the cryftallized falt takes place. The remainder after being kept fome time in a low red heat to expel all the acid, is the perfect black oxyd of copper weighing 32 parts, one-fifth of which is oxygen and the remainder copper. Hence 100 parts of this falt, according to Prouft, confift of

Copper	25.6	} forming Black Oxyd }	32.0
Oxygen	6.4		
Sulphuric Acid	.	.	32.
Water	.	.	36.
			100.0

Bergman alfo reckons 26 per cent of copper in this falt, but only 28 of water and 46 of acid.

Prouft alfo defcribes a *sub-fuphat* of copper, or with a lefs quantity of acid. To procure it, add potafh to a folution of the common fuphat, but not enough to precipitate the whole of the metallic oxyd. A *green* precipitate then appears, which is the fub-fuphat in queftion. If faturated with the alkali the precipitate is *blue*, and is of a different nature, confifting of a fingular compound of oxyd of copper with water, called by the fame eminent chemift *hydrat of copper*, which will be prefently mentioned.

The fub-fuphat lofes by diffillation only 14 per cent. of water. The refidue boiled with cauftic potafh gives 68 of the black oxyd, whence its component parts are

Copper	54.4	} 68.0
Oxygen	13.6	
Water	.	14.
Sulphuric Acid		18.
		100.0

Sulphat of copper is of course decomposed by all the alkalies pure or carbonated. If a solution of blue vitriol is poured into liquid potash, or if the latter is added to the former to complete saturation, a *blue* precipitate falls down, which, when thoroughly washed with much boiling water, gives that peculiar combination first discovered by Proust, and called by him *Hydrat of Copper*.

This substance when dried at a heat not above that of boiling water, has not exactly the consistence of a powder, but rather that of Prussian blue. With a heat somewhat higher it shrinks and gradually becomes converted to the black oxyd. By dry distillation it is found to lose in its passage to the state of black oxyd 24 per cent. of its weight, which is nothing but water, and about 1 of carbonic acid, which last it appears to absorb from the air in drying, and 75 parts of the black oxyd remain. If this last is again moistened with water it does not return again to the state of hydrat, nor assume any other but the brownish black colour of the pure oxyd. Hence it appears that the hydrat is a true chemical combination of about 3 parts of oxyd of copper with one of water, and as Mr. Chenevix has well observed, enters as such into the composition of the cupreous salts. Therefore sulphat of copper (for example) might, with more propriety be said to be thus composed.

Copper	25.6	} forming Hydrat of Copper	{ 42.6
Oxygen	6.4		
Water	10.6		
Sulphuric Acid			32.0
Water of Crystallization			25.4
			100.0

The hydrat is still better formed from the nitrat by the addition of potash, and also from all the other cupreous salts. In all cases its water is separated either by heat, or by *boiling* with potash.

Sulphat of copper is decomposed by double affinity by many other salts. With common salt, muriat of copper is formed, and this is seen at once by the change of colour of the solution from blue to green. Sulphat of copper

and acetite of lead produce the acetite of copper, and this is a convenient method of preparing this salt as will be further mentioned.

Copper unites readily with carbonic acid, and this combination, like the former, is also found largely in nature, the analysis of which has already been noticed. Whenever copper is exposed to a damp confined air it readily rusts, and the green crust formed on its surface is also a carbonated oxyd. But the readiest way of producing the carbonats artificially, is by adding a carbonated alkali to the sulphat, nitrat, or any other acid salt of copper. A very copious bulky green precipitate is collected, which, well washed, and gently dried, forms a beautiful apple-green powder often used as a pigment in various forms. A hundred parts of copper dissolved in any acid, and precipitated by carbonated potash or soda, produce invariably 180 of the green carbonat, dried at a boiling-water heat. This carbonat distilled without addition with a heat gradually increased to redness, gives out 10 parts of water, and 46 of carbonic acid, and at last 125 parts of the black oxyd remain in the retort, which quantity (as already mentioned) is precisely that which is left when the green carbonat is boiled with potash, and is therefore also equal to 100 of metallic copper. To preserve the uniform green colour, for which the carbonat is valued, it should be repeatedly washed with boiling water, the heat appearing to increase the density of the precipitate, and of course the body of colour. An excess of the carbonated alkali redissolves part of the carbonated oxyd.

When the hydrat of copper is gently heated with a solution of carbonat of potash supersaturated with carbonic acid, a part is dissolved, forming a greenish-blue liquor^m, whilst the residue remains at the bottom, of a colour approaching to that of the black oxyd. The solution, slowly evaporated, yields a singular salt, being a carbonat of potash, holding no more than 5 per cent of oxyd of copper, and 43 of carbonic acid. It is slightly deliquescent and crystallizable. A similar salt, but with the basis of soda, is formed, when carbonat of soda is used.

Copper dissolves in nitric acid with extreme ease, when moderately diluted, and even in the cold. Much heat is excited, and if the solution goes on vigorously, a torrent of *Nitrous Gas* is given out (which indeed is one of the most convenient modes of procuring this gas) at the same time that the solution becomes of a deep blue.

The oxyds of copper dissolve equally in nitric acid, but without the production of gas. When the solution is hastily evaporated to a certain point, and suffered to cool, it congeals into a deep-blue saline mass, which again redissolves spontaneously, if kept exposed to air. A slow careful evaporation gives this salt in the form of six-sided prisms, but very deliquescent and intensely acrid. If this blue nitrat be evaporated beyond the point at which it would crystallize when cold, nitrous gas comes over, and a green scaly concretion begins to separate from the thick blue liquor, and incrusts the inside of the retort. If the distillation is here stopped, this green concrete may be separated by water which dissolves only the still undecomposed blue nitrat, and does not touch the other. Proust considers this green substance as a *sub-nitrat* of copper, or having a deficiency of acid, to which it owes its insolubility in water, hot or cold, and its peculiar properties. It is proved to be still a nitrat, by giving out this acid when the sulphuric is added. By thorough calcination all the acid and water are expelled, and the black oxyd of copper alone remains, which weighs exactly 125 parts when 100 of reguline copper have been used, and therefore is precisely similar to the black oxyd left by boiling any cupreous solution with potash, so often mentioned. The same chemist gives the following proportions of the sub-nitrat.

Black oxyd of copper	67
Nitric acid	16
Water	17
	100.

The blue or perfect nitrat on the other hand contains only 27 per cent. of the black oxyd.

The nitrat of copper is very soluble in alcohol. This salt burns with a remarkably fine blue-green flame when thrown on burning charcoal.

The decomposition of this nitrat by tin is so violent and rapid, as in certain circumstances to produce actual combustion. This forms an amusing experiment, first noticed by Dr. Higgins, and is thus performed. Spread out a piece of tin-foil the size of half a sheet of paper, lay on the middle a small heap of the solid blue nitrat, a little moistened, and over it a few filaments of tow, then double up the tin-foil round it on all sides, twisting it as tight as may be without breaking. In a very short time it will feel burning hot, small bubbles of the blue liquor will be seen oozing through the foil, and

soon a copious stream of nitrous gas will shoot out from the different openings, attended with minute flashes of light and deflagration. A little sprinkling of water will assist the effect.

A fine blue pigment is prepared from nitrat of copper, called *Verditer* (*Cendres Blues Fr.*) It is made in quantity, chiefly, if not entirely, by the refiners, who, after the process of separating gold from silver by aqua-fortis, recover the silver from its solution by means of copper, and thus leave a residue of nitrat of copper. This solution decomposed by lime, the particular mode of which is kept a secret, made up into cakes, and dried gently, forms the best kind of verditer. The research made into the nature of this valuable pigment by Pelletier,^a is interesting in a chemical point of view.

The analysis of this pigment gave the following particulars: it was totally soluble in nitric and muriatic acids with much effervescence of carbonic acid: when distilled without addition, 600 grains lost 200 grains, and gave 2 (French) pints of gas almost totally carbonic acid, together with a small portion of water. The loss on 100 grains is therefore $33\frac{1}{3}$, of which the author of the experiment reckons 30 grains to be carbonic acid, and the remaining $3\frac{1}{3}$ to be water. The calcined residue was a black substance, which was fused with a reducing flux, left a button of pure copper, and (making some allowance for the loss by this mode of reduction) was estimated to amount to 50 per cent, of the original verditer. By the separate treatment of another portion by sulphuric acid, sulphat of lime was produced, the earth of which amounted to 7 grains from 100 of the verditer. Consequently there remains $9\frac{2}{3}$ to complete the 100, which is estimated to be oxygen. Pelletier therefore gives the following result from his analysis.

	grains
Carbonic acid	30.
Water	$3\frac{1}{3}$
Lime	7
Copper	50
	$90\frac{1}{3}$
Remains for oxygen	$9\frac{2}{3}$
	100.

It is obvious however that there must be a great error in this estimation in the very small quantity of water allowed, since it is shewn by Proust, and since by other chemists, that in all the blue or green salts of copper, a large quan-

^a Memoires, tom. 2.

tity of water remains in their compositions, and is expelled, when by calcination the cupreous salt is converted to the black or brown oxyd as was the case in this instance. It is fortunate that the experimenter himself enables us to correct the error, (which is merely that of computation) without obliging us to impeach the accuracy of so excellent a chemist. From the *facts* given, therefore, we may safely correct the results in the following manner.

The button of copper actually obtained from the residue was in the proportion of 49 per cent. of the verditer, which (considering the unavoidable loss by saline fluxes) may fairly be taken, with the author, at 50.

Fifty grains of copper require 12.5 of oxygen to be reduced to the state of the black oxyd, which, as we have already seen, is the degree of oxygenation in which the metal exists in the nitrat. This again (according to Proust) would require 20.8 of water to bring it to the state of hydrat. But it is also clear that the weight of carbonic acid is much over-rated through some singular oversight. The quantity actually obtained from 600 grains of verditer was about 2 French pints, the weight of which, according to Lavoisier, would be only 66 French grains, and consequently 100 grains would yield only 11 of this acid. The quantity of water was obviously only estimated at random. The corrected result therefore of Pelletier's experiments would be,

	grains	
Copper	50.	} 83.3 Hydrat of Copper
Oxygen	12.5	
Water	20.8	
Lime	7.	
Carbonic acid	11.	
	101.3	

which corresponds very closely with the quantity analyzed. It may be added, however, that a very great difference in the proportion of ingredients is found in the different sorts of verditer. The above analysis is of the best sort.

The same chemist's experiments on the composition of this curious colouring matter are equally interesting. The precise difficulty appears to be to preserve the blue colour, and prevent it from acquiring the shade of green, which properly belongs to the carbonats of copper. If nitrat of copper, or any other cupreous solution is precipitated by a carbonated fixed alkali, the colour is a deep apple-green. This, when

rubbed with lime, assumes a fine blue at first, but by desiccation it again returns to nearly its original green. It appears necessary, therefore, to use lime as the precipitant in the first instance, and not a carbonat, but here also M. Pelletier found by varied trials that the precipitate was at once blue when somewhat more lime was added than was necessary entirely to decompose the nitrat, but when the ingredients approached to mutual saturation, or especially if the cupreous solution was in excess, the colour became green. This last however became blue by a fresh addition of lime, and in this method he proposes to make the colour, as follows: add lime to a dilute nitrat of copper, just or hardly sufficient to decompose the whole. This gives a greenish precipitate, which should be well washed and nearly dried on a cloth strainer. Then rub it with a fresh portion of lime, from 8 to 10 per cent. of its weight, which will immediately give it a fine and permanent blue, and dry it slowly. The precise quantity of lime and precipitate must be determined by experience, and by the shade of colour produced during the mixture, observing that lime will heighten the blue, and the green precipitate will soften it.

The Muriatic acid dissolves copper with difficulty, except when concentrated and boiling, when hydrogen gas is given out; but its oxyds with much more ease, particularly the green watery oxyd. Thus if plates or shreds of copper be only moistened with muriatic acid, and exposed to the air, the surface very speedily becomes covered with a green muriated oxyd, which a fresh quantity of the acid of very moderate strength will easily dissolve; and by repeating the process, a very strong solution may be made. This solution, when hot, or very highly concentrated, is brown, but by dilution becomes grass-green. By careful evaporation and cooling the salt crystallizes in rhomboidal prismatic parallelipeds, with some varieties,^o or when more hastily conducted, in feathery crystals. These are commonly deliquescent, but when both the copper and the acid are free from iron they are permanent.^p This salt is very soluble in water and alcohol. The latter takes up its own weight when boiling, and part separates again in very perfect crystals. The composition of this crystallized salt is thus given by Proust^q.

Black oxyd of copper	40
Muriatic acid	24
Water	36
	100.

^o Pelletier, tom. I.

^p Leonhardi.

^q An. de Chim. tom. 32.

The quantity of muriatic acid was determined by nitrat of silver. The watery solution of muriated copper, when sufficiently dilute, makes a kind of sympathetic ink, which is colourless in the cold, becomes yellow by warming, and again loses its colour on cooling.*

Chemistry is further indebted to the ingenious researches of Proust for the discovery of another species of muriat of copper, in which the metal appears to be less oxydated than in that already described, which makes a nearly colourless solution, and when solid is of a greyish-white. It is therefore termed for distinction the white muriat of copper, and was first noticed in investigating the remarkable disoxydating properties of the muriat of tin.*

Most of the salts of copper, and the muriat in particular, if combined with muriat of tin recently made, undergo a remarkable change. The latter salt, on account of its extreme attraction for oxygen, robs the cupreous salt of a portion, and reduces it to the state of a muriated oxyd which collects at the bottom of the vessel, and is white at first, but by exposure to light passes to the different shades of blue, violet and black. In this state it melts in the fire like luna cornea. This white muriat (or more properly *muriated sub-oxyd*), if heated with muriatic acid, dissolves therein, and crystallizes, by cooling, in tetrahedrons. With nitric acid, some nitrous gas is given out, as with reguline copper and this acid, which shews that the sub-oxyd decomposes a portion of the acid in order again to saturate itself with oxygen. The solution is nitro-muriat of copper. Another remarkable character of this white muriat is, that when dissolved in ammonia it is not at first blue, as all the other ammoniated solutions of copper are, but quite colourless, as long as kept from the external air.

The white muriat formed as above mentioned by the solution of tin, when analyzed by solution in nitric acid, precipitation by nitrat of silver for the quantity of muriatic acid, and by an alkali for the metallic part, gave as follows.

Muriatic acid	24.75
Oxyd of tin	1.
Metallic copper	63.
Remains for oxygen	11.25
	100.0

Assuming this analysis as correct, it is obvious that the copper exists in a much lower state of

oxygenation in this salt than in any hitherto mentioned, for in this, the oxyd of copper is composed of 63 of copper and 11.25 of oxygen, or (reduced to the hundred) of 84.84 of copper and 15.16 of oxygen: whereas the *Black oxyd*, to which all the common cupreous salts are reducible by loss of their acid and water, consists of 80 per cent. of copper and 20 of oxygen. The former therefore is properly distinguished as a *sub-oxyd*, and when combined with muriatic acid, as the white muriat, may be termed the *muriated sub-oxyd*.

The reader will now understand what takes place on distilling the common green muriat of copper without addition. The first effect is to expell merely any excess of acid and the water of crystallization, after which, by encreasing the heat, oxymuriatic acid comes over, (composed of the proper acid of the salt, and the quantity of oxygen which makes the difference between the perfect oxyd and the sub-oxyd) and a grey melted mass remains, which is chiefly the white muriat, or muriated sub-oxyd.

When this is exposed to the air for a day or two, it is again converted into the common green muriat. Part of the copper is itself volatilized, however, as is seen by the beautiful blue-green flame which the heated muriat gives to any burning matter.

There appears to be yet another state of combination of muriatic acid also noticed by Proust. It is the *sub-muriat of copper*, or a salt that differs from the common muriat, not by a lower degree of oxygenation of the metal, but in an inferior proportion of muriatic acid. It is produced by adding a little potash, (less than to saturation), to the green muriat. A green powder falls down, which is the sub-muriat, and corresponds with the sub-nitrat already described. If an excess of potash is added, the salt is entirely decomposed, and the precipitate is the *hydrat*.

This sub-muriat boiled with potash loses about 28 per cent. of its weight, and is reduced to the *Black oxyd*. A similar sub-muriat is said by the same chemist to be spontaneously deposited when copper is dissolved in nitro-muriatic acid, and its composition is given as follows:

Black oxyd of copper	79
Muriatic acid	12.5
Water	8.5
	100.0

The green native muriat of copper of Peru

appears to be nearly in this state. By heat it becomes brown, but regains its colour on exposure to air.

Some experiments of Mr. Chenevix¹ throw further light on the nature of the sub-oxyd and muriated sub-oxyd above mentioned. It was noticed on the analysis of the red octohedral copper ore that this substance was a pure oxyd, consisting of about 88.5 of metal and 11.5 of oxygen, and therefore in a much lower state of oxygenation than in any hitherto observed. This ore on the affusion of nitric acid dissolved therein *with a rapid disengagement of nitrous gas*, shewing thereby the necessity of a more compleat oxydation of the metal to enable it to unite with the remaining undecomposed portion into common nitrat of copper. Muriatic acid was then tried, and was added to 100 parts of the ore. The liquor became hot and the ore dissolved therein into a brown fluid, but which turned green on exposure to air. Iron separated 88 parts of metallic copper, leaving only 12 for the oxygen, which in the proportions of the common black oxyd, would only have indicated 48 of copper instead of 88; but as the whole 100 parts were dissolved, it was proved that no part of the ore could have been a mixture of reguline copper and black oxyd, since reguline copper is not soluble in cold muriatic acid, and hence it appears a legitimate conclusion that the red octohedral ore is really a distinct and before unknown *sub-oxyd* of copper. On adding water to the concentrated muriatic solution, a very copious white precipitate subsided, which became orange on further washing with water, and appeared to be the *muriated sub-oxyd*.

A similar muriated sub-oxyd of copper Mr. Chenevix also produced artificially by mixing 57.5 parts of the black oxyd with 50 parts of the pulverulent regulus of copper obtained by precipitation by iron, and which may readily be reduced to a fine powder. This dissolved almost entirely in cold muriatic acid, which is a curious circumstance, since before the solution of the reguline part could have been effected, it must have taken a sufficient portion of oxygen from the black oxyd; and thus (the one by taking and the other by losing oxygen) both would be reduced to the state of a sub-oxyd, there being no more than 11.5 of oxygen in the black oxyd, which, by this distribution, proved sufficient to render nearly 90 parts of copper soluble. It may be here remarked that a sub-oxyd of iron is made in a similar manner by mixing the perfect oxyd with iron filings and heating

moderately, the result of which is the black *sub-oxyd* or *ethiops* of iron.

Copper appears to have a stronger affinity for the muriatic acid than for the nitric or even the sulphuric. Thus, according to Cornette,² if either the solid nitrat or sulphat of copper be added to muriatic acid, a solution takes place with the production of cold, and if it is heated it immediately loses the blue colour peculiar to these two salts, and acquires the green of the muriat. Also if the liquor is slowly evaporated muriat of copper is obtained in crystals.

The Acetous acid does not act upon reguline copper, but when oxydated it dissolves it with ease into a fine green liquor readily crystallizable. There is also with this, as with many of the other cupreous salts, a distinct state of *sub-acid* and of saturated salt. Both the sub-acetite and the acetite of copper are the products of a domestic manufacture carried on to a considerable extent in the South of France, and therefore require a fuller description: the sub-acetite being the common verdigris of the shops (*verdet*), and the acetite, being the crystallized, or distilled verdigris, as it is called, (*crystaux de Venus—Verdet cristallisé.*)

This manufacture, in its present somewhat improved state, is thus described by Chaptal³ as carried on at Montpellier.

The materials for this manufacture are, 1st. Any refuse matter of the ripe grape, the stalks, seeds, &c. but more particularly the *marc* or the cake that remains in the wine-press after the greater part of the juice has been extracted. This when fermented produces the acid requisite to corrode the copper. 2d. Plates of copper of convenient size and previously hammered well to smooth the surface, in order that the corroded portion may be conveniently detached, without which preparation too much of the copper would peel off in scales, without being thoroughly penetrated by the acid.

The marc of the grape, which may be kept for a good while by being close packed in casks, is first fermented, simply by being laid loosely in a large barrel, moistened with water (or better with wine) and set in a warm airy place. After a while, sometimes in a day, at other times in two or three weeks, it heats, swells, and gives a strong smell of vinegar, and when the fermentation subsides it is fit for use. The richer the grape juice of course the better is the marc and the more perfect will be the subsequent fermentation, on which much of the quality of the verdigris depends. Hence it should not be

¹ Ph. Trans. for 1801.

² Mem. de l'Acad. for 1779.

³ Ann. Chim. tom. 25.

too closely pressed, or, if poor, it should be moistened with a little ordinary wine. To determine when the marc is sufficiently fermented, a small copper plate is buried in it for twenty-four hours, and if fit, the plate will come out covered uniformly with a green crust. The plates are then all heated scorching hot over a pan of charcoal, and laid regularly in earthen pots with a layer of the fermented marc at bottom and at top, and interposed between each plate. The pot is then loosely stopped with straw, and the whole left at rest from ten to twenty days. These earthen pots (the same in which the marc is fermented) are about 16 inches high, and 14 in diameter, and the mouth 12 inches. Each holds about 30 or 40 pounds of copper plate, with the requisite quantity of marc. When the plates are used for the first time they are previously prepared by being rubbed with a rag dipped in a solution of verdigris in water, and suffered to dry. Without this the first produce of verdigris is apt to be black. This is not required a second time.

The earthen pots are emptied when the marc begins to whiten, and if the process has gone on well, the copper plates are found covered with a green crust interspersed with distinct silky green crystals. They are then taken out (the marc being thrown away) and set on end face to face on wooden racks in a cellar; and when dry they are dipped in water (formerly in wine) and again set to dry, and this is repeated once a week for six or eight times which makes them swell, and in every way improves and encreases the crop of verdigris, which is finally scraped off with a knife without difficulty. Every pot yields about five or six pounds of rough verdigris, and the plates, after this is separated, will serve again repeatedly till they are corroded quite through.

The verdigris is sold by the maker in the rough state, and is further prepared by being well ground in wooden mortars and exposed to the air on skins till sufficiently dry, in which process it loses nearly half its weight. The whole of the manufacture of the rough verdigris is a part of household business in the wine-farms about Montpellier, and is generally done by the women. It requires little attendance, and no other capital than the expence of the copper plates and earthen jars.

Verdigris thus prepared may be considered as copper oxydated by the action of the acetous acid of the fermented materials, united with water, and a small portion of undecomposed

acetous acid, together with part of the extractive or mucilaginous matter of the marc. Its exact composition will be presently mentioned. In this state it is insoluble, or nearly so, in water. The colour is a fine green, and it is used more largely as a pigment than any other cupreous preparation.

Verdigris is however completely soluble in an additional portion of vinegar, and the result is the perfect *acetite of copper*, a beautiful crystallizable salt, sold at a very high price in the shops under the name of *distilled verdigris*. It is prepared from common verdigris in Holland and France, and Montpellier; the process which is followed at the latter place is very simple, and is thus described by the same accurate observer. Common vinegar is first distilled in a copper alembic, which seems to be a process constantly going on in the small way in most of the vintage farms in the neighbourhood. This is put with common verdigris into a copper boiler, and when a hot saturated solution is made, it is strained and let off to another copper evaporating vessel, where it is boiled down till a crust of the salt appears on the surface. A light frame of sticks in cross-bars is then sunk in the liquor and the fire put out. On cooling, the acetite of copper crusts around the sticks in most beautiful clusters of rhomboidal crystals of a fine deep blue-green colour. When these are dried and finely powdered they form a green pigment of great beauty and value. It requires about three pounds of verdigris to make one pound of the crystallized acetite. The part which remains undissolved in the vinegar consists of an imperfect oxyd or acetite which used to be thrown away, but, as Chaptal has observed, when moistened occasionally with vinegar, and exposed to the air, it yields a fresh quantity of verdigris, and is then readily soluble in vinegar.

From the analysis of several chemists there appears to be very little uniformity in the proportion of the ingredients of the common verdigris, but according to Chaptal two kinds are particularly distinguished in France, that of Montpellier, and that of Grenoble. The latter is prepared in a different manner from that already described, no fermented refuse of the vintage being here used, but the process is chiefly to dispose plates of copper in a proper room, and to moisten them repeatedly with distilled vinegar till the surface is sufficiently oxydated and converted into verdigris.

In consequence of this difference in the pre-

paration, a certain difference is found in the appearance of the two kinds, that of Montpellier having a soft greasy feel^v, and shewing in its fracture a number of silky filaments like some kinds of malachite, and also being almost insoluble in water. The other kind is dryer and harsher to the touch, of a deeper colour, breaking more like the crystallized salt, and more soluble in water. The former is somewhat cheaper and is preferred in painting, the latter is more used in dyeing. The analysis of each by distillation *per se* with a graduated fire, slowly increased till every thing volatile was expelled, gave as follows.

A hundred parts of the verdigris of Grenoble gave

Carbonic acid	-	-	-	9.10
Water weakly acidulous	-	-	-	13.05
Strong, coloured acetous acid				53.95
Copper	} left in the	-		20.90
Charcoal		retort	-	3.00
				100.00

A hundred parts of the verdigris from Montpellier gave

Carbonic acid	-	-	-	8.00
Acetous acid very weak and very	}			65.15
empyreumatic				
Copper	-	-	-	22.50
Charcoal	-	-	-	4.35
				100.00

In comparing these products it will be found that the difference may principally be explained from the different mode of manufacture. It may be premised that the products thus obtained by fire are by no means in the same state of combination in which they exist in the salt: the heat decomposing much of the acetous acid, (besides what is simply expelled) and thence producing carbonic acid in abundance, and probably oxyd of carbon not noticed in this analysis, whilst the oxyd of copper is also decomposed, the oxygen uniting with the new compounds, and the copper being left very nearly in the metallic state, and mixed with a little charcoal from the vegetable matter. From the much less quantity of acetous acid, and the greater degree of empyreuma in the product of the Montpellier verdigris than in the other, it is reasonably inferred to contain more extractive matter, and less acid in its natural state, as might be expected, where an imperfectly fermented refuse matter is used instead of pure

acetous acid in the manufacture. The Montpellier kind therefore is a sub-acetated oxyd of copper mixed with vegetable extractive matter: the Grenoble kind is almost pure sub-acetite, and the part soluble in water is doubtless the perfect acetite.

The analyses both of verdigris and of the acetite of copper as given by Proust, shew a very different proportion of ingredients in the sub-acetite from that just mentioned. As the oxyd of copper is the only substance actually obtained in Proust's analysis, the difference may be explained, partly by the different state of dryness of the substance on which these two chemists operated, and partly by supposing that the one took the entire verdigris, and the other the pure sub-acetite separated from common verdigris by diffusion in water. Proust observes, that when verdigris is put into cold water it gradually falls to pieces, near one-half is dissolved (and hence the kind here examined more approaches that of Grenoble) and the remainder is a very fine green powder which diffuses itself through the water, and subsides extremely slowly, together with the accidental impurities of the copper. This green powder appears to be the purest sub-acetite of copper, and when washed and dried weighs about 42 per cent. of the original verdigris. When sulphuric acid is poured on it pungent vapours of vinegar are given out. Boiled with potash, a black perfect oxyd of copper is obtained, in the proportion of 63 from 100 of the sub-acetite. Distilled *per se* the products are the same in kind with those of the acetite of copper (which will be presently mentioned) and the residue is 52 per cent of copper almost in the metallic state, but not entirely, since cold diluted sulphuric acid is coloured blue by remaining in it, dissolving the small portion of oxyd of copper, and leaving the metallic part untouched. According to this analysis therefore, 100 parts of the fine green sub-acetite extracted from verdigris by diffusion in water and dried, are composed of

Copper	50.4	} forming the black oxyd	63
Oxygen	12.6		
Remains for acid and water	-		37
			100.

Acetite of copper (meaning the crystallized and perfectly saturated salt, or the *distilled verdigris*) may be produced, for experiment, simply by saturating distilled vinegar with oxyd of

copper, and crystallizing, but this will not readily afford a salt of that fine colour for which the acetite made from verdigris and distilled vinegar is so much valued. According to Proust 39 parts of the black oxyd produce with distilled vinegar 100 parts of the acetite; and on the other hand 100 parts of the salt decomposed by boiling potash, give 39 or 40 of the black oxyd. Hence its composition is thus deduced.

Copper	31.2	} making of black oxyd	} 39
Oxygen	7.8		
Acetous acid	.	.	61
			100.

The distillation of the acetite of copper furnishes that pungent concentrated acid called *radical Vinegar*, the preparation of which is perfectly simple, and is described under the article *Acetous Acid*. In this case as in the distillation of common verdigris, the operation of the heat modifies, and considerably alters the arrangement of the component parts of this salt. Though by estimation it is reckoned to contain about 60 per cent. of acetous acid, no more than about 52 are obtainable by distillation, the remainder being changed by the heat, and by the oxygen of the copper (7.8 per cent.) and new products being formed probably by very complicated affinities. These products are partly carbonic acid and carburetted hydrogen, and partly, as it appears, a portion of empyreumatic oil, which, towards the end of the process, gives a peculiar smell and colour to the acid. A small quantity of the acetite sublimes as a white salt in the neck of the retort, or covering the upper part of the heated mass, which appears to be the acetite, little, if at all altered, except by losing some of its water of crystallization.*

After the distillation, a brown powder remains in the retort, which last is also sometimes lined with a thin film of metallic copper. This brown powder is copper, almost metallic, but still containing some oxygen, and also mixed with charcoal, according to M. Adet, in the following proportions in 90 parts, viz. Charcoal, 4.50; Copper, 78.66; and Oxygen, 6.84.

The entire products of the distillation of acetite of copper, as given by M. Adet, may here be inserted as they appear considerably accurate. The undecomposed portion of 288 parts of the salt was 25.5, deducting this, and reducing the remainder to the centesimal proportion it will be as follows:

Acetous acid	53
Copper	30.
Charcoal & Oxygen	4.3
} forming the residual brown powder	
} 34.3	
Remains for gas given out	12.7
	100.0

The 30 parts of metallic copper (which were actually obtained by subsequent reduction,) are equivalent to 37.5 of black oxyd in the undecomposed salt, a quantity not much differing from that given by Proust.

On account of the very high price of the distilled verdigris, many experiments have been made by chemists to produce an equally fine acetite of copper by a shorter method. Where the object is merely that of yielding radical vinegar by subsequent distillation, it is not difficult to combine acetous acid with any of the cupreous oxyds, or carbonated oxyds, and to produce a saturated acetite, with or without regular crystallization; but to form the beautiful blue-green salt for the painter or dyer is not so easy. The double decomposition of acetited lead and sulphat of copper, as mentioned under *Acetous Acid*, appears to succeed the best, the sulphat of lead being entirely separable by mere subsidence, and the green supernatant liquor affording by evaporation a very fine crystallized acetite of copper.

The natural combinations of copper with Arsenic and Arsenic acid have already been fully mentioned, together with the general mode of analysis. With regard to the artificial arseniats, Scheele† found that when arsenic acid was digested with copper filings a green solution was formed, and a blue arseniat also precipitated. The sulphat, nitrat, and muriat of copper undergo no apparent change by arsenic acid, but the acetite is decomposed, and arseniat is precipitated. But all the cupreous salts are decomposed by double affinity, by arseniated alkali of any kind; and a blue arseniat of copper falls down. Mr. Chenevix also has the following experiments: Arseniat of ammonia was added to nitrat of copper, which caused a double decomposition, and arseniat of copper fell down in blue crystalline grains. On evaporating the clear liquor and adding alcohol, another copious deposition of crystals took place after a while, which were of a still deeper blue and rhomboidal, and were also arseniat of copper, and not nitrat of copper, this latter salt being soluble in

* Adet, An Chim. tom. 27.

† Essays.

alcohol, and therefore not precipitable by it. Each of these arseniats was examined separately, first by calcination in a low red heat to expel the water, then by potash to obtain the black oxyd of copper, and lastly by nitrat of lead to estimate the arsenic acid. By this method the first arseniat was found to consist of

Oxyd of copper	50
Arsenic acid	27
Water	22

99

The second deeper-coloured arseniat consisted of

Oxyd of copper	35.
Arsenic acid	39.5
Water	24.

98.5

Arsenic, in the state of white oxyd when combined with oxyd of copper, forms a grass-green powder, first noticed by Scheele, and commonly called in chemistry *Scheele's Green*. It is formed by decomposing arseniated potash by sulphat of copper, by double affinity. The nitrat or any other salt will answer the same purpose. The inventor's process for making it in quantity is the following: Dissolve 24 ounces of sulphat of copper in water in a copper vessel over the fire; and, separately, in another copper vessel, 24 ounces of fine pearl ash, and 11 oz. of white arsenic in water, also with heat, and strain each solution separately through linen; then add the arseniated potash, little by little, to the sulphat of copper, with constant stirring, which will immediately effervesce, and then will let fall a green powder. When the whole is mixed, let it stand some hours, edulcorate well with clear hot water and dry very gently in a warm room. From the above quantities 18½ ounces of the green powder are obtainable, which may be used as a pigment.

Phosphat of copper may be made artificially by adding phosphat of soda to nitrat of copper, or any other cupreous salt. A blueish-green sediment settles, which dries to a powdery mass mixed with crystals. A low red heat turns it brown and drives off all the water. It loses by this 15.5 of pure water. The residue is a phosphat of copper, consisting of 35 of phosphoric acid and 49.5 of oxyd of copper.

A striking decomposition of nitrat of copper also takes place when a stick of fresh-melted phosphorus is immersed in this cupreous solu-

tion and exposed to light. By degrees the copper is precipitated in the metallic state on the phosphorus in crystalline grains.

The Prussic acid forms a red-brown salt with oxyd of copper. All the cupreous salts are decomposed by prussiat of potash or of lime, and the colour of the precipitate (which nearly resembles that of metallic copper without the lustre) is different from that of any other prussiat, and hence this may occasionally be used as a serviceable test. By drying, the colour changes to a dark chocolate hue.

Tincture of galls added to the cupreous solutions gives a dirty yellow precipitate.

All the other acids dissolve the oxyds of copper, forming salts little known and of small importance. In all of them, green in its various shades is the predominating colour.

Of the Alkalies, neither potash nor soda have any action on copper or its oxyds, except that (so often mentioned) of depriving the wet precipitated oxyds of their water of combination, by the help of a boiling heat, and bringing them to the state of the black oxyd, composed simply of about 80 per cent. of copper and 20 of oxygen.

The carbonated fixed alkalies however dissolve oxyd of copper by help of the carbonic acid, and by evaporation a triple salt of carbonic acid, alkali, and oxyd of copper may be obtained, as has been already mentioned.

Ammonia has no action on metallic copper, but dissolves its oxyds with ease. The usual colour of this solution is a most beautiful deep blue, and it is made in a variety of ways. The most direct way is to put together any oxyd or carbonated oxyd of copper and liquid ammonia in a phial, and digest them. The liquor becomes blue almost immediately, which colour deepens till the alkali is saturated. By slow evaporation carefully managed, the ammoniated copper may be got in fine blue silky crystals. Alcohol added when the solution is quite concentrated, much assists the crystallization. This salt loses its alkali by exposure to air, and at the same time absorbs carbonic acid, so that at last a green carbonat is left. Another method of making the ammoniated copper is to digest in a glass vessel lime, muriated ammonia, verdigris, and water. The lime first decomposes the muriated ammonia and disengages the alkali, which then dissolves the oxyd of copper, and very soon produces a fine blue liquor, consisting therefore of ammoniated copper and muriated lime. Lime water will answer as well, where only a weak

solution is wanted. The same materials will succeed without the verdigris, if made in a copper vessel exposed to the air. Both these solutions form the Aqua Sapphirina in pharmacy, used sometimes as an external application in some surgical cases. Another method of producing ammoniated copper immediately, is to supersaturate with ammonia any of the salts of copper. Thus the first portion of this alkali added to muriated copper (for example) which is of a light green, separates a green oxyd of copper; more of the alkali redissolves the oxyd, and the liquor now shews the fine blue, which indicates an ammoniated solution. In this way ammonia becomes a very excellent test for the presence of copper, distinguishing it by the colour and the clear solution from every other metal except nickel.

Carbonat of ammonia will answer the same purpose as pure ammonia in the above processes, the carbonic acid being mostly expelled during the mutual action. This however is not necessary, since carbonat of ammonia, as such, will also dissolve oxyd of copper and retain it in a solid state. A simple mixture, by trituration, of one part of solid sulphat of copper and three parts of dry carbonat of ammonia effervesces strongly, and when carefully dried, forms a mixed blue salt, the *cuprum ammoniatum* of pharmacy.

A singular circumstance takes place with ammoniated copper. If a bottle be filled full of liquid ammonia with a few clean copper filings, and kept closely corked, no solution ensues. * If the bottle be now opened for a while and then shut, part of the copper is dissolved, but the liquor is still colourless, till on again uncorking the phial, when it suddenly becomes blue at the top, and this colour spreads slowly down to the bottom. A fresh addition of copper filings, and again closing the vessel, causes the blue colour again to vanish, but this is restored by the access of air. To explain this fact an observation made by Proust may be added, which is, that the white muriated *sub-oxyd* of copper (formed by the solution of tin and already described) when supersaturated by ammonia in a close vessel, is indeed decomposed by it, and an ammoniated solution is formed, but colourless, till exposed to the action of air, when it becomes blue. It appears probable therefore that copper requires to be only slightly oxygenated to dissolve in ammonia, but in this state is colourless, and has a strong attraction for that additional dose of oxygen which is necessary to

give the beautiful blue by which the common ammoniated solution is distinguished. In the experiment above mentioned it is also probable that the copper filings added to the blue solution partly disoxygenate and deprive it of colour, and themselves are thereby in part dissolved, unless the alkali be saturated.

Copper is in time oxydated and partially dissolved by almost every saline substance, even those that are perfectly neutralized, such as common salt. This is proved by the fact that all copper vessels long in contact with any saline matter and exposed to air, become gradually covered with a green crust of oxyd. This is also observable in copper-bottomed ships, from which, when the old sheathing is ripped off, a very large portion chips off in half-corroded scales. The decomposition by muriated ammonia is very rapid, and a green muriated oxyd remains, which is said to be the basis of the *Brunswick Green*.

When muriated ammonia and copper, or better, its oxyd, mixed dry are heated in a close vessel, the muriat, in subliming, carries up with it a portion of the metal (as it does with many, if not most other metals) and greenish-yellow flowers are collected, which consist of muriated ammonia, with a small and varying portion of oxyd of copper, generally about $\frac{1}{4}$. A part of the muriat is at the same time decomposed and ammoniacal gas is given out.

Copper and sulphur readily unite. When equal parts of copper filings and flowers of sulphur are mixed and heated in a crucible much of the sulphur burns off, but the remainder melts into a deep bluish-black mass, which is an artificial sulphuret of copper. According to Proust^b 100 parts of copper take up in this way 28 of sulphur, so that the sulphuret is composed of about 79 of metallic copper and 21 of sulphur. This combination contains no oxygen, and is therefore a simple *sulphuret* of copper, and not a *sulphuretted oxyd*. It is more fusible than copper, readily melting at a red-heat. By roasting in the open air, the sulphur is expelled, and then an oxyd of copper remains, (as with the native sulphurets) but the last portions of sulphur adhere with great obstinacy. Dr. Thompson^c also has found sulphur and copper filings to unite by merely being mixed together in the cold, with or without water, and remaining long exposed to the air.

Hydro-sulphuretted water, or any of the liquid hydro-sulphurets added to the solutions of copper produces a deep blueish-black pre-

* Gren.

^b An. Chim. tom 38. p. 172.^c Elem. of Chemistry.

cuprate, which is a hydro-sulphuret of copper.

Phosphorus unites with copper by fusion, and forms a hard steel-grey brittle alloy. This combination was observed by Pelletier, in the preparation of phosphorus in the great way. The phosphoric acid from bones being commonly evaporated in a copper vessel dissolved a small portion of the metal, and in the subsequent distillation of this vitreous phosphoric acid with charcoal, several metallic globules were often found in the residue, arising from the reduced copper uniting with and keeping down a portion of the phosphorus.

Phosphuret of copper may be made according to Pelletier^c in two ways: in one (imitating the accidental discovery) 8 parts of copper filings and 8 of vitreous phosphoric acid are intimately mixed with 1 of charcoal powder, and then being put into a crucible and covered with a little more charcoal powder, are heated intensely. In this process, part of the reduced phosphorus burns off, but the rest combines with the copper forming a hard grey brittle alloy, capable of a high polish. In the other method which is simpler, copper filings are made red-hot in a crucible, and pieces of phosphorus are carefully and repeatedly projected on the metal which immediately melts down into the same grey phosphuret. A hundred parts of copper may be increased by this means to about 120, and in this state the specific gravity, according to Sage,^d is 7.122. This phosphuret, if kept in fusion exposed to the air, loses gradually most of its phosphorus, which burns with the bright flame and smell peculiar to this substance.

Phosphuret of copper is more fusible than copper. If kept in fusion covered with charcoal powder, or under melted glass of any kind so as not to be exposed to the action of air, it loses all the excess of phosphorus which it may contain, above that quantity which is equivalent to an increase of one twelfth of the weight of the copper,^e after which it remains unaltered in any continuance of close fire. This therefore seems to be a point of mutual saturation, and this phosphuret is therefore composed of about 7.7 of phosphorus and 92.3 of copper. This phosphuret has the grain and colour of steel, takes a very high polish, and remains very long untarnished in the air, but is brittle. With a less proportion of phosphorus it again becomes malleable and of a yellowish-white colour, so that it is possible that this may be found useful (with other additions) in producing a white

alloy, which would be serviceable in manufactures.

The fixed oils when kept some time in contact with copper oxydate and dissolve a portion, and thereby become green.

The alloys of copper are so numerous and important that they will be separately described in the following article.

The uses of copper, in all its various states, are almost endless, and only, if at all, inferior in number to those of iron. Besides the variety of uses for which copper and its alloys are employed in the metallic state, various pigments and dyeing materials are obtained from its salts, and the oxyd is used to give an emerald green to coloured glasses and enamels.

All the salts of copper are more or less poisonous, producing violent nausea, and the severest pain and inflammation of the alimentary canal. Yet from the sudden vomiting which they excite, a large dose may be given with safety, and this is sometimes used when it is necessary immediately to empty the stomach. Copper is however very little used medicinally in any form.

The affinities of the oxyd of copper are given by chemical writers in the following order.^f The gallic, oxalic, tartareous, muriatic, sulphuric, nitric, arsenic, phosphoric, succinic, fluoric, citric, acetic, boracic, prussic, and carbonic acids; ammonia, and fixed oil.

COPPER, *Alloys of.*

The alloys of copper (that is, those in which this metal predominates) are more numerous and more important in the arts than those of any other metal. Many of them are perfectly well known, and have been in use from very ancient times; of many the exact composition, and particularly the mode of preparing, are kept as secret as possible; for even when the precise composition of an alloy is found by chemical analysis, it may often be extremely difficult to produce a mixture by common methods, which shall have exactly the same shade of colour, the same malleability, texture, susceptibility of polish, or some other excellence, which, perhaps, a mere accident has discovered to the possessor. Another circumstance of infinite consequence to the manufacturer is the ordinary state of purity of the materials he employs, and this alone will account for the great superiority of one manufacture over another; thus the Swedish copper is commonly purer than the British, and makes more malleable alloys, the English tin better than most of the foreign, and the like.

^d Jour. de Phys. tom. 38,

^e G. B. Sage, Jour. Phys.

^f Grer.

The principal objects of alloying copper appears to be to render it less liable to tarnish, and especially to be acted on by common animal or vegetable substances, (which, when used for culinary purposes, is of extreme importance): to make it more fusible, and harder, and able to take a higher polish; and to alter its colour either to a golden yellow or a silvery white. All these objects are attainable by different alloys.

Copper with Gold, Silver, and Platina.

These are seldom if ever used in the proportions in which they would be alloys of copper, being much too costly for any purpose of manufacture, considering the great deterioration of the more valuable metals; with this exception, however, that a very small portion of silver much improves the composition of the alloy of copper and tin, when used as bell-metal or speculum-metal. This will be afterwards noticed. Copper is used largely as an alloy of gold and silver, and it is often plated with one or the other. This subject we shall refer to these metals respectively.

Copper with Arsenic.

Arsenic has beyond any other metal the effect of whitening copper, but as it is readily evaporated in fumes at less than a red heat, and therefore at a temperature much below the melting point of copper, some management is required to effect a combination of the two. For this purpose, first melt the copper in a crucible, then wrap up in paper some white arsenic mixed with a little charcoal, or else reguline arsenic, or even white arsenic alone, or, as some recommend, arsenic and potash, and with a long pair of tongs thrust it to the bottom of the melted copper. The arsenic immediately rises through the copper, and most of it burns off in dense white fumes, but a certain portion is retained. The mixture should be immediately cooled. It seems somewhat a more convenient way to put the arsenic in a small crucible, inverting it over the melted copper and forcing it down to the bottom, holding it there till all the arsenic has passed through.^s By repeating this several times, the copper may probably be more fully saturated with arsenic, observing each time to give no more heat than requisite.

This alloy is quite white, of a very close texture, but perfectly brittle, and where the arsenic is sufficient entirely to destroy the yellow of the copper it is liable to tarnish in the air, the more in proportion to the dose of arsenic. As soon as it melts the arsenic begins to escape,

and on account of the extreme volatility of this ingredient it is impossible to combine accurate proportions, so that always enough arsenic must be used, to allow for a considerable loss. When kept long in fusion, the copper regains its malleability in proportion as the arsenic escapes, but even when it has become quite malleable, the colour does not entirely return to the original copper-red, but long remains of a dingy yellow.

Vauquelin^h has observed, that when equal parts of silver and copper are alloyed (which by themselves make a pale yellow mixture) the addition of so little as 2 of arsenic to 100 of the alloy gives a perfect whiteness, whilst the ductility and malleability remains. Beyond 5 per cent. of arsenic the alloy begins to be brittle, without increasing in whiteness.

Arsenic is used in small quantity in some of the more compound white alloys of copper, particularly in speculum-metal.

Copper with Manganese.

Attempts have been made to whiten copper and retain the malleability by alloying with manganese, but with little success. The combination is difficult, and seems to require two processes. First, let copper and oxyd of manganese with charcoal be mixed, and put into a crucible lined with charcoal, and heated very intensely. This gives a black, crumbly, granular, semi-metallic mass, consisting of the metals partly combined, and of some of the charcoal. The whole of this again fused under borax, gives a metallic button of a dirty yellowish white, hard, and somewhat malleable.ⁱ

If the combination is attempted by a single process and a flux used, the manganese and flux will melt together, and will corrode the crucible long before any reduction can take place.

Copper with Iron.

These only unite when the iron is in small quantity. The alloy is grey, hard, and somewhat brittle.

Tutenag is a white alloy of copper, zinc, and iron, according to Keir,^k which is very hard, tough, and sufficiently ductile to be wrought into various articles of furniture, such as candlesticks, &c. which take a high polish, and when made of the better sort of tutenag are hardly distinguishable from silver. The inferior kinds are still white, but with a brassy yellow.

The Chinese *Petong* is another fine, white, malleable alloy of copper, the composition of which is not exactly known, but it contains a

^s Jour. Phys. tom. I.

^h An. Ch. tom. 39.

ⁱ Gmelin in Comment. Gotting. vol. 9. and own Experiments.

^k Notes to Macquer.

small portion of silver. Neither of the above metals are imitable by the common processes.

According to Dizé,¹ when the iron forms only $\frac{1}{8}$ of the mass it is still magnetical, but not so when it is only about $\frac{1}{16}$. Iron does not whiten copper so much, in equal quantities, as tin does, and still less than arsenic.

Copper with Lead.

These metals unite to appearance very intimately by fusion, but, what is very remarkable, when a mass of this alloy is exposed to a heat less than that at which the whole melts, the lead alone sweats out, leaving almost all the copper in a porous or honeycombed state. When the copper holds a small portion of silver, the lead carries the latter out with it, and this is the principle of the old process of *eliquation*, formerly much used in the extracting of SILVER from copper ores. Copper with about a fourth of its weight of lead forms *pot-metal*.^m The antient Roman pot-metal, according to Pliny, was composed of 100 of copper, 2 of lead, and 2 of tin. The same ingredients, but with more of the two latter, were the materials of many of the ancient Greek and Sicilian coins.ⁿ

Copper with Zinc.

Copper nearly saturated with zinc, that is, in which the latter makes about a fourth (more or less) of the mixture, forms *brass*, the most important of all the alloys of this metal, and which has been fully described under that article. With a much less proportion of zinc the colour of the alloy approaches very nearly to that of gold, and the malleability increases. Mixtures chiefly of these two metals are used to form a variety of yellow or gold-coloured alloys, known by the names of *Tombac*, *Manheim or Dutch Gold*, *Tinsel*, *Similor*, *Prince Rupert's Metal*, *Pinchbeck*, &c. but the precise composition varies according to the fancy or the experience of different manufacturers. The Dutch gold may be beaten out into extremely fine leaves, which, when fresh, have nearly the brilliance of gold-leaf, and are used as a cheap imitation of it, but they tarnish very soon. The mixture may be made either by directly melting copper and zinc, or by mixing brass and copper. In either case the copper should be melted first, and the zinc added afterwards, the whole stirred together with wood, covering it with a little charcoal, and poured out immediately, to prevent the loss by the burning off of the zinc.

Several direct experiments on the union of copper and zinc in different proportions were

made by Margraaf.^o In all, the copper was the purest Japanese, and the mixture was made in the way above mentioned. With 8 drams of copper and as much zinc, much of the latter unavoidably burnt off and the alloy only weighed 12 instead of 16 drams, the mixture was hard, brittle, yellow, and of a radiated texture. With 16 drams of copper and 8 of zinc, the loss by burning was only $\frac{1}{8}$ of a dram. The alloy was softer than the last, still radiated, yellow, and began to be a little malleable. From this, successively diminishing the proportions of zinc, the alloy became softer, more malleable, and of a colour more and more approaching to gold: and at last, with 11 or 12 of copper and 1 of zinc, the finest golden tombac was produced. According to Wiegleb^p the Manheim gold is made by melting separately 3 parts of copper and 1 of zinc, mixing them, covering with charcoal, stirring with a stick and cooling immediately. These proportions scarcely differ from those of some kinds of brass. Beaumé gives for the same metal 4 of copper and 1 of zinc, whence it is obvious that the proportions are quite arbitrary, but it appears that the alloy is not made, as brass is, by cementation, but by simple mixture of the metals. A very small quantity of tin is sometimes employed, but this metal has the disadvantage of remarkably diminishing the malleability of copper and its alloys. A fine malleable tombac is made, however, with 16 of copper, 1 of zinc, and 1 of tin. An alloy of 12 of brass and 1 of tin is scarcely malleable.

A kind of tombac is the material of which a large proportion of the Roman coins was composed. Klaproth^q on analyzing several, struck during the first century of the emperors, found them all to consist either of pure copper, or of copper and zinc, in which the latter metal made generally from a fifth to a sixth of the mass. A little tin and lead were found in some, but in such small proportion as to appear only an accidental impurity.

Copper with Tin.

The alloys of copper and tin are extremely important in the arts, and curious as chemical mixtures. They form in different proportions mixtures which have a distinct and appropriate use. Tin added to copper makes it more fusible, much less liable to rust or corrosion by common substances, harder, denser, and more sonorous. In these respects the alloy has a real advantage over unmixed copper, but this is in

¹ Jour. Phys. tom. 36.

^m Watson's Essays, vol. 4.

^p Leonhardi Worterbuch.

^o Klaproth.

^q Mem Acad. Berlin, 1774.

^r Phil. Mag. vol. 17.

many cases more than counterbalanced by the extreme brittleness, which even a moderate portion of tin imparts, and which is a singular circumstance considering how very malleable both metals are before mixture, and the remarkable softness and ductility of tin.

The sensible qualities of the different mixtures are the following. Copper alloyed with from 1 to about 5 per cent. of tin is much harder than before, the colour yellow with a cast of red, and the fracture granular. It is still considerably malleable. This appears to be the usual composition of many of the very ancient copper tools and weapons before the common use of iron; whence it appears that the ancients did not (as has often been supposed) possess any peculiar art of hardening pure copper, otherwise than by mixture. It is certain that the quenching of red hot copper in water will not at all make it harder, or have any such effect as it has upon iron. An alloy in which the tin is from $\frac{1}{10}$ to $\frac{1}{8}$ of the whole is hard, brittle, but still a little malleable, close-grained, and yellowish-white. Where the tin is as much as $\frac{1}{6}$ of the mass, it is now entirely brittle, and continues so in every higher proportion. The yellowness is not entirely lost till the tin is above $\frac{2}{3}$ ds of the whole.

Copper, or sometimes copper with a little zinc, alloyed with as much tin as will make from about $\frac{1}{10}$ to about $\frac{1}{2}$ of the whole, forms an alloy which is the principal, and often the only composition for bells, brass cannon (so called) bronze statues, and several smaller purposes, and hence it is called *Bronze*, or *Bell-Metal* (always observing that there is no perfect uniformity in the different alloys under these names, either in the proportion or the actual number of ingredients) and it is excellently fitted for these purposes, by its hardness, density, sonorousness, and fusibility, whereby the minute parts of hollow moulds may be readily filled before it fixes in cooling. For cannon, a lower portion of tin seems to be used. According to Dr. Watson,* the metal used at Woolwich is 100 parts of copper and 8 to 12 of tin. Hence it still retains some little malleability, and of course is tougher than with more tin. Bronze cannon are much less liable to rust than those of iron, but in large pieces of ordnance, by very rapid firing the touch-hole is apt to melt down and spoil the piece; of which there is a remarkable instance at the Tower of London of a mortar of the largest calibre thus spoiled at the siege of Namur. On account of the sonorous-

ness of bronze, these cannon give a much sharper report than those of iron, which for a time impairs the hearing of the people that work them. A common alloy for bell-metal is about 80 of copper to 20 of tin; or where copper, brass, and tin are used, the copper is from 70 to 80 per cent. including the portion contained in the brass, and the remainder is tin, and zinc. The zinc certainly makes it more sonorous. Antimony is also often found in small quantity in bell-metal. Some of the finer kinds used for small articles contain also a little silver, which much improves the sound.

When the tin is nearly one-third of the alloy it is then most beautifully white, with a lustre almost like that of mercury, extremely hard, very close-grained, and perfectly brittle. In this state it takes a most beautiful polish, and is admirably fitted for the reflexion of light for all optical purposes. It is then called *speculum metal*, which however, for the extreme perfection required in modern astronomical instruments, is better mixed with a very small proportion of other metals particularly arsenic, brass, and silver. But the basis of these compositions is copper alloyed with nearly half its weight of tin. The use of this alloy for the same purpose is of great antiquity, and certainly was in frequent use in the time of Pliny. Klaproth analyzed a portion of an ancient speculum in the following manner. The fragment was compact, very hard, and brittle, the fresh fracture greyish white, which by polishing acquired a beautiful lustre. A hundred grains were heated with nitric acid, whereby a blue solution was made, and a part remained undissolved. The solution being first tried without effect with muriatic acid for silver, was mixed with a solution of sulphat of soda, which gave a white precipitate of sulphat of lead, equivalent to 6 grains of lead. The copper was then separated by iron, and amounted to 62 grains. The undissolved portion slowly digested with muriatic acid, gave a straw-yellow solution, which, decomposed by zinc, gave 32 grs. of metallic tin. This speculum therefore consisted of 62 parts of copper, 32 of tin and 8 of lead, which last was probably an adulteration of the tin and not added designedly.

When more tin is added than amounts to half the weight of the copper, the alloy begins to lose that splendid whiteness for which it is so valuable as a mirror, and becomes more of a blue-grey. As the tin increases, the texture becomes rough-grained, and, as it were, rotten,

* Dizé. Jour. Phys. p. 36.

* Essays.

and totally unfit for manufacture. The speculum metal is therefore in the highest proportion of alloy of tin that copper will admit for any useful purpose.

A perfect speculum-metal should be quite white without shewing any cast of yellow when polished, not very liable to tarnish, quite free from pores even when examined by a lens, of a certain coherence or toughness to bear the grinder, and for the convenience of working, as soft as may be consistent with the other requisites.

Mr. Mudge, whose specula were celebrated for their goodness, observes, that the extreme of whiteness is given by 32 parts of copper and 16 of tin,^{*} but this is excessively hard and brittle; that 32 of copper with $14\frac{1}{2}$ of tin is still quite white and as hard as can be wrought. He also observed by many trials, that the metal to turn out free from pores should be twice fused, that is, the first time for the purpose of mixture (in which the copper is to be first melted separately) and then remelted with as little heat as possible, for casting. As there is always some loss by the calcination, chiefly of the tin, a little allowance in the proportion of this latter may be made on account of the double fusion.

The most elaborate mixture and accurate directions on this important subject are given by Mr. Edwards, whose specula are of extreme excellence, and are published in the nautical almanac for 1787,^u of which the following are the leading particulars.

The quality of the copper should first be tried by adding successively from so much short of half its weight of tin that it proves a little yellow, to the full half of tin, and by comparison ascertaining the maximum of whiteness, observing that beyond this point the alloy begins to lose part of the brilliance of fracture and to become bluish. When this is found, take 32 parts of the copper, melt it, add one part of brass and as much silver, with a little black flux to cover the surface; when these are melted, stir with a wooden rod, and pour in from 15 to 16 parts of tin (according as found necessary by previous experiment) fused in a separate crucible with a low heat, stir the mixture again, and immediately pour it into cold water. Then in the second melting (with as little heat as will suffice) take for every 16 parts of the composition 1 part of white arsenic, wrap it in paper, thrust it to the bottom of the fluid metal, and stir with a wooden rod till no more arsenical fumes escape, immediately after which cast the metal in a sand-mould. Then while it is still

red-hot lay it in a pot full of very hot embers and cool it very slowly: unless this precaution is particularly observed, the metal will fly in pieces when cold, sometimes even long after all such danger is thought to be past; or it will split in the polishing. For the particular manner of constructing the mould, and the whole of the nice and laborious operations of grinding and polishing to a perfectly true figure, the reader is referred to the two papers above mentioned.

Both the brass, and the silver, and the arsenic appear to have their distinct use. The brass makes the mixture tougher and not so excessively hard and brittle. The silver improves both the texture and colour, but is not an essential though really an useful addition. The arsenic is found by actual comparison to make the metal finer, and particularly closer in texture, and therefore less liable to be porous. It sensibly increases the specific gravity, which, before the arsenic is added, is 8.78, but afterwards, 8.89. It is added in the second melting, that as little as possible may be dissipated in vapour. A greater proportion would make the metal liable to tarnish. An alloy containing 6 of copper, 2 of tin, and 1 of arsenic, is nearly the proportion of Sir I. Newton's specula, which is very good, but polishes somewhat yellow.

The separation of copper from bell-metal and all the tin alloys in the large way, happened to be an object of considerable importance in France in the midst of the revolutionary war, when the importation of copper was nearly impracticable, and a large quantity of it was required for general purposes, and particularly for the coinage. A number of very ingenious experiments were then made on the best method of freeing the metal of church bells from their tin and other alloy, and obtaining thence a good malleable copper with the least possible expence or loss.

The circumstances in which it is worth while to melt down great bells for the sake of the pure copper do not often occur, but the various processes may be here shortly noticed as important to the history of the chemical properties of copper alloys, and as a very happy example of the application of theoretic chemistry to the purposes of manufacture. Pelletier^x and Fourcroy^y seem to have chiefly distinguished themselves in this research, and each chemist appears to have followed nearly the same track, but with an acknowledged priority in the former.

^{*} Phil. Trans. vol. 67.

^u or Nicholson's Journal, 4to, vol. 3.

^x Memoires, tom. 1 & 2.

^y An. Chim. tom. 9.

The great principle on which all the modes of purifying bell-metal depend, is the much more ready oxidability of tin by the united action of heat and oxygen, than copper. Hence even when bell-metal is simply kept melted in an open vessel, a degree of separation of the two metals begins instantly, the tin oxidating much faster and sooner than the copper, and of course the proportion of copper being therefore constantly increasing in the fluid metal below.

Another equally important circumstance also depending on the much stronger affinity of tin for oxygen is, that when oxyd of copper is mixed with tin at its lowest state of oxygenation, the tin still retains its superior affinity for oxygen, and deprives the oxyd of copper of this principle, and the products are, tin highly oxygenated and in a pasty semi-fluid mass, and copper in the reguline state, partly collected at the bottom of the vessel and partly in small globules entangled in the oxyd of tin.

The direct experiments of Fourcroy on this point are valuable.

A bell-metal was first made with 80 parts of copper and 20 of tin, both pure.

Of this alloy 100 parts were put on a muffle and exposed for a certain time to a red heat, with access of air. The whole was converted to a grey oxyd and weighed 104 parts. It was then heated strongly for half an hour, and yielded a button of pure copper weighing 54 parts. Consequently 26 parts of copper remained unreduced and mixed with the scoriae of the oxyd of tin.

A hundred parts were calcined as above till they increased to 117. This being strongly heated for half an hour gave a brown mass, from which no copper separated, except a few interspersed globules. This therefore was too much oxygenated, that is, the tin had combined with so much oxygen in the first operation that it could not afterwards separate any from the oxyd of copper.

A hundred parts were treated in the same way till they increased to 112. This melted into a brown mass containing more globules of copper than the last, but still the greater part remained unreduced.

Hence it appears that even an increase of 12 on 100 is too much, and by other experiments, the above chemist fixes the proper point of oxidation at which oxyd of copper is reducible by oxyd of tin to be from 5 to 7 on 100 of common bell-metal. However, when too highly oxygenated metal is mixed with the requisite

proportion of fresh metal, the former serves as a reducing flux to the latter, and the whole may then be made to yield a large portion of purified copper. This very ingenious plan has been found to answer extremely well in experiments made in the large way, as will presently be mentioned.

Several substances have been tried that might assist in the first oxygenation of the bell-metal and shorten the process. Of these, nitre and oxyd of manganese answer the most completely. For experiment in the small way, 100 parts of bell-metal were powdered and mixed with about 14 of nitre, and heated, at first slowly, afterwards strongly, and gave from 57 to 63 parts of copper, very malleable, but not quite pure. With a larger quantity of nitre the copper is purer, but more is lost in the scoriae.

A hundred parts of bell-metal mixed with 25 parts of oxyd of manganese, covered with broken glass, and strongly heated for an hour, gave 36 parts of very good copper. It is of some importance to add glass or some other saline flux, as this brings the whole into thorough fusion, and allows the copper to subside through the vitrified oxyd of manganese. Where this is not done (and in the large way it would add to the expense) much of the copper is entangled in the vitrified manganese, and a subsequent operation is required to separate it.

In the processes of two other chemists, salt and sand have each been found useful additions in the refining of bell-metal.

We may add the detail of two trials made in the large way by ²Pelletier and Darcet by order of the French government, the one in which a portion was first oxydated, and this used as a reducing flux for the remainder, without any foreign addition whatsoever: and the other in which the refining was assisted by oxyd of manganese. It may be premised that the manipulation of large quantities is not the same as with small, particularly in the case of reduction to gross powder, which may be easily done in an iron mortar on a few ounces or pounds, but not with any economy on large weights. Large masses therefore are first heated red-hot, when they may be easily broken up and spread about by an iron bar, and this is the way constantly practised.

The first process was that of refining without addition. For this purpose 400 pounds of metal were put on a furnace, and when red-hot broken up with an iron bar, and spread about with constant stirring till the whole was con-

verted into a reddish oxyd, somewhat cohering, and shewing the appearance of copper approaching to reduction. The 400 lbs. were increased hereby to 425 lbs. 2 ounces, making an increase of above $6\frac{1}{4}$ on 100.

Next, 800 lbs. of fresh metal were melted on a reverberatory, and the 425 lbs. 2 ounces of oxyd were added to it with constant stirring for about 20 minutes. The fire was continued for nine hours with occasional stirring of the metal, and samples were drawn from time to time, which shewed a gradual approach in the melted metal to the state of pure copper. As the refining took place at the surface of the fluid metal, or the point of contact between it and the scoria, the metal was there purer than at the bottom. Nine hours after the melting of the metal the copper beneath the scoria was fine, red, and fibrous, and was then run off into moulds. The scoria remained in for half an hour longer to melt out part of the metal entangled in it, which was then let out, and lastly, the scoria itself was raked out, which was a black and pasty mass that hardened excessively when cold, and still contained some copper entangled in its substance. The results of this operation were 761 lbs. 12 ounces of copper run into the moulds; 46 lbs. of copper sweated out of the scoria, and 7 lbs. 4 ounces of small-grained copper, samples, &c. or in total 915 lbs. of copper from 1200 of metal, or nearly 68 from 100. The scoria weighed 474 lbs. and when thoroughly bruised in a stamping mill, and washed, it gave 18 lbs. more of copper.

Thus then by this simple process nearly 70 parts (in all) of very good copper may be got from 100 parts of metal. whose known contents of copper are about 80 per cent.

The second process was that with the assistance of black oxyd of manganese.

In the same furnace 800 lbs. of bell-metal were first melted, and kept very hot, after which 25 lbs. of oxyd of manganese were thrown in, and the whole stirred and mixed with great care. Two hours after, 15 lbs. more of the manganese were stirred in, and the metal even then was sensibly purer than at first. This alternate addition of manganese, and stirring, continued till 100 lbs. of manganese were used, during which the metal constantly kept refining. Ten hours after the first melting, the copper was found to be soft, fibrous, and good, and was run off into moulds. It weighed 520 lbs. The scoria was softer than the former, and not so well melted. It weighed 344 lbs. and was still visibly rich in copper, as was proved by

after washing. The copper, exclusive of that in the scoria, here amounted to about 60 from 100 of bell-metal.

From these and many other experiments it appears that by very simple means from six to seven eighths of the copper actually contained in bell-metal may be extracted; and in particular circumstances this may be practised to advantage, but on the other hand the tin is lost to most economical uses, as its reduction from the state of an impure semi-vitrified scoria is extremely difficult and expensive.

COPPERAS is a kind of generic term synonymous with *Vitriol*, and applied in commerce and manufacture, with the distinction of *blue*, *green* and *white*, to the metallic salts the sulphates of *copper*, *iron*, and *zinc*.

CORAL. This beautiful substance formerly much employed in medicine, is now (in this country at least) entirely reserved for ornamental purposes. Chemical analysis shews it to be composed almost entirely of carbonat of lime organized by means of a portion of animal membrane. See SHELL and BONE.

CORK. *Kork*, Germ. *Liege*, Fr.

Cork is the bark of an evergreen oak (*Quercus suber* Linn.) that grows in the southern parts of Europe, and on the shores of the Mediterranean: it is stripped off every three years in large masses from two to three inches in thickness, and of a somewhat curved figure corresponding with that of the trunk of the tree. The only preparation which cork undergoes is that of being flattened; for this purpose it is scorched on both sides to soften it, and in this state is laid between flat heavy planks till it is cold. Cork is of a light brown colour, and a very fine spongy texture, is very soft, but requires an extremely sharp knife to cut it smoothly, a dull one only tearing it. It is considerably elastic, and its sp. gr. is no more than 0.24, hence it is the most buoyant in water of any ligneous substance. It has a faint peculiar aromatic odour, and little or no taste. It is readily inflammable, burning with a large yellow flame, which, however soon goes out of itself, and leaves behind a bulky, soft, impalpably pulverulent charcoal.

Water, by long decoction with cork, acquires a brownish colour, and takes up a quantity of extractive matter in the proportion of about 40 grains from an ounce; of the residue alcohol takes up 11 grains. An ounce of cork digested first in alcohol lost 42 grains, and by subsequent decoction in water 8 grains more. From the spirituous tinctures a powdery matter precipitated, of a reddish colour when the cork had

not been previously boiled with water, but otherwise of an ash-grey.^a

Cork is corroded, and almost entirely dissolved by nitrous acid, and in 1787 Brugnatelli repeating this experiment, thought that a peculiar acid was thus produced. The investigation was afterwards taken up by B. La Grange with the following result.^b He took finely rasped cork, and added to it in a retort six times its weight of moderately strong nitrous acid. By digestion at a moderate temperature nitrous gas is given out, the cork swells and becomes yellow, and finally is almost entirely dissolved. When the red vapours cease, the liquor is to be transferred into a glass capsule, and is to be gently evaporated till it becomes thick, and a pungent vapour begins to be disengaged. A substance is thus procured of the consistence of thick honey, of a lemon-yellow colour, and a lively, penetrating, aromatic odour. In order to separate the acid generated in this process from the other matters with which it is mixed, the whole is to be dissolved in twice its weight of hot distilled water, and passed quickly through a filter, by which a small quantity of an inflammable substance analogous to wax will be separated. The clear liquor is of a light amber colour with an odour approaching to that of prussic acid. By refrigeration it becomes turbid, and deposits a pulverulent sediment which is the acid of cork, or suberic acid. The acid yet remaining in the mother liquor may likewise be obtained by repeated evaporation and cooling. The suberic acid thus prepared is of a yellowish-brown colour, but may be whitened by being boiled with fresh burnt charcoal. When pure it is in a solid form, but not crystallizable; it is acidulous and bitter to the taste, is volatilizable by a moderate heat, decomposes all the metallic and many of the earthy salts, and combines with the alkalis into crystallizable salts. Hence it is considered by La Grange as a peculiar acid, and Fourcroy has ranked cork, under the name *Suber*, as one of the vegetable principles.

The two chemists however, above-mentioned, appear to have been led into an error from not having examined the composition of cork previous to treating it with nitric acid, on which account the following facts^c may not be unacceptable to the reader.

If cork previously reduced by filing to extremely fine powder, is digested with alcohol, a brownish-yellow tincture is produced, possessing the faintly aromatic odour of cork, and causing

a slight ochery precipitate in red sulphat of iron: this alcoholic solution being evaporated to dryness by a very gentle heat, leaves behind a brittle brownish sediment, of a somewhat astringent taste, and considerably inflammable. By digestion with water a portion of it is dissolved, consisting principally of gallic acid and tannin; for it forms a black precipitate with red sulphat of iron, and throws down a curdy insoluble precipitate from a solution of isinglass. The portion insoluble in water appears to be chiefly resinous, and this, no doubt, it is which marks the peculiar characters of the gallic acid in the alcoholic solution. After alcohol has extracted from cork all that it is capable of taking up, the residue, when digested in a weak solution of caustic potash, acquires a deep reddish-brown colour, which it communicates to the menstruum. Muriatic acid added to saturation nearly destroys this colour without occasioning any sensible turbidness, nor does the neutralized solution produce any change in red sulphat of iron, so that it is probable that the alkali dissolves little or nothing but a small quantity of carbon. Hence it appears likely that the suberic acid of La Grange is only gallic acid converted by nitrous acid into oxalic acid, and combined with a little resinous extract; and that the *suber* of Fourcroy consists of vegetable fibre in a very loose state, mixed with resinous and extractive matter, and a little tannin and gallic acid.

CORK, MOUNTAIN. See ASBEST.

CORROSIVE SUBLIMATE. See MERCURY, Muriat of.

CORUNDUM.^a Of this mineral there are the three following sub-species.

1. *Telefia*. *Perfect Corundum*, Bournon. *Telefie*, Haüy. *Saphir*, Werner. *Sapphire*, *Oriental Ruby*, &c. of the jewellers.

Telefia exhibits a great variety of colours. It is pearl-grey, bluish-white, lavender blue, sky blue, azure or indigo-blue, and then is the sapphire of the jewellers; or it is peach, crimson, cochineal, and very rarely carmine red, and is then called oriental ruby; hence it passes into violet coloured, forming the oriental amethyst; when yellow or reddish yellow it is denominated oriental topaz; when yellowish-green, oriental chrysolite; and when of a deep somewhat brownish green it is named oriental emerald. The colours are for the most part uniformly distributed, but sometimes two or more occur in the same specimen.

It occurs in small rounded pieces or crys-

^a Neumann, ii. p. 228.

^b Manuel de Chim. ii. p. 414.

^c Orig. Experiments.

^d Greville, Bournon, Chenevix, and Tennant, in Phil. Trans. for 1798 and 1802. Jamieson, Haüy, Brochant.

tallized in a slightly acute rhomboid or double trihedral pyramid (its primitive figure) of which the obtuse angles measure 94° , and the acute ones 86° .

1. Sometimes the acute solid angles, or the summits of the pyramids, are replaced by planes perpendicular to the axis, situated either above or below, or exactly corresponding with the short diagonal.

2. Sometimes the edges of the base of the primitive rhomboid are each of them replaced by a plane parallel to the axis, thus separating the two pyramids by a hexahedral prism with rhombic planes: when the prism is long the terminal pyramids often entirely disappear.

3. Sometimes the flat angles of the primitive pyramids that rest on the common base are replaced by two new planes, thus rendering the pyramids enneahedral as long as any of the primitive faces remain, but when these are obliterated forming a dodecahedron, composed of two hexahedral pyramids united base to base. This modification is often combined with No. 1. in consequence of which the summits of the dodecahedron are more or less truncated.

4. The acute angles composing the solid angle at the summit of the primitive rhomboid, are sometimes replaced by secondary planes so inclined to the axis as to form a very obtuse secondary rhomboid.

The variety in the form of a hexahedral prism (No. 2.) appears sometimes to contain within it a similar prism but of a different colour. The crystals are small and very small, rarely middle sized. It is commonly more or less transparent passing into translucent. The lustre of the transparent kinds is shining and vitreous; of the translucent kinds generally glistening. When those crystals, in which the summits of the primitive rhomb are replaced by secondary planes, are translucent, the planes just mentioned present that varying lustre which is called *chatoyant*: and if these crystals are cut *en cabochon*, or in the form of an ellipse, taking care that the summit of the ellipse shall be situated exactly under the point corresponding with the summit of the rhomboid, there will then be produced the appearance of a star with six rays. Such stones are highly valued by the jewellers, and are called *star-stones*.

The fracture of the blue varieties of *Telefia* is conchoidal passing into foliated; that of the other varieties is foliated. The fragments are indeterminately angular. Its hardness is only inferior to that of the diamond, and the blue varieties are uniformly somewhat harder than

the others. It gives fire with steel, but not very easily. By collision it becomes luminous like quartz, and the light from the red varieties is a very deep fire colour or cherry-red. Its mean specific gravity is about ≈ 4 . but it varies from 3.907 to 4.161.

It is infusible *per se* before the blowpipe, but when finely pulverized is soluble in borax and partially in potash. Its extreme hardness, and the powerful affinity that subsists between alumine and silice, render it difficult to analyse. According to Bergman, sapphire is composed of 35 silice, 58 alumine, 5 lime, and 2 oxyd of iron. An improved analysis of the same gem was made by Klaproth (by means of caustic potash) with the following results:

98.5 Alumine,
0.5 Lime,
1.0 Oxyd of iron.

100.0

Finally, Mr. Chenevix succeeded, by the help of borax, in decomposing this stubborn mineral, and his analyses of the sapphire and ruby may perhaps be looked upon as the most correct of any.

	Sapphire.	Ruby.
Silice	5.25	7
Alumine	92.	90
Iron	1.	1.2
	98.25	98.2
Loss	1.75	1.8

Telefia occurs in veins in granite and syenite. It is found in the kingdom of Pegu and the island of Ceylon in the East Indies. It seems to have been found by Count Bournon in the province of Forez in France, and has been met with in the bed of the brook Expailly, in the same country. It is said also to have been discovered in Portugal and Bohemia; and in the North of Italy by Professor Pini.

All the varieties of *Telefia* are valuable in jewellery; but rubies, if not very small, bear a considerably higher price in proportion to their weight than sapphires or any of the other varieties. It is said that the light violet coloured pieces may be rendered colourless by being heated in a charcoal crucible, without impairing any other of their properties, and that such pieces are often sold for diamonds.

II. ADAMANTINE SPAR. *Imperfect Corundum* of Bournon; *Corund* and *Demantspath* Werner; *Corindon* Haüy; *Spath adamantine* Broch.

Its colour is greyish or greenish-white, or yellowish-green, or sapphire blue, or purplish-red, or reddish-brown. It occurs massive, disseminated, and crystallized in the same figures as Telefia. The crystals are middle-sized and large. Externally they are for the most part dull and rough, internally they are translucent, semi-transparent, and sometimes, though very rarely, transparent. Their surface is often covered by strongly adhering spangles of mica and grains of magnetic iron ore, which last is sometimes found dispersed through the interior of the crystals. Its internal lustre is shining or glistening, between vitreous and resinous. The terminal faces of some of the crystals are chatoyant

like Telefia. Its longitudinal fracture is stratified; its cross fracture is small and imperfectly conchoidal. Its fragments are rhomboidal. Its hardness is considerably superior to that of quartz, and the blue and red varieties are the hardest. It gives fire with steel, but not very easily. It becomes luminous by friction in the same manner as Telefia. Its mean sp. gr. is ≈ 3.931 , varying on the one hand as far as 3.875, and on the other to 3.981.

Adamantine spar, in its chemical properties, agrees with Telefia. Its component parts according to Klaproth and Chenevix are as follows:

	Adamantine Spar from Bengal <i>Klaproth.</i>	from the Carnatic, <i>Chenevix.</i>	from Malabar <i>Chenevix.</i>	from China <i>Chenevix.</i>	from China <i>Klaproth.</i>	from Ava <i>Chenevix.</i>
Silex	5.5	5.	7.	5.25	6.5	6.5
Alumine	89.5	91.	86.5	86.5	84.	87.
Iron	1.25	1.5	4	6.5	7.5	4.5
	96.25	97.5	97.5	98.25	98.0	98.0
Loss	3.75	2.5	2.5	1.75	2.	2.0
	100.	100.	100.	100.	100.	100.

It occurs in veins in granite and syenite and other primitive mountains in India, China, and Ava. From its extreme hardness, it is in great request in the East for polishing steel, and for cutting and polishing gems. The European lapidaries however prefer diamond-powder on account of the greater rapidity with which it works,

III. EMERY. *Schmiergel* Werner.

Its colour is intermediate between greyish-black, and bluish-grey. It occurs massive and disseminated; when in mass it is generally incrustated with magnetic iron ore, pyrites and mica; the latter substance frequently penetrates the whole mass, giving it when broken a silvery appearance. It possesses a glistening or glimmering lustre. Its fracture is fine-grained, uneven, passing into even splintery. It is about equal in hardness to adamantine spar, cutting flint and rock crystal with great ease. It is heavy, and not easily frangible. When most free from iron it consists, according to Tennant, of about

Silex - 3.4
Alumine 92.
Iron - 4.6

100.

When highly impregnated with iron it consists of about

9 Silex
55 Alumine
36 Iron

100

Emery is chiefly procured from the Islands of the Archipelago, especially from Naxos. It is also found at Ochsenkopf in Saxony, in beds of talc and steatite, accompanied by calcareous spar and blende.

It is largely used for cutting and polishing by lapidaries, and workers in glass, steel, &c.

The substance called by Count Bournon compact corundum, and which accompanies adamantine spar, is probably an intermediate variety between emery and adamantine spar. Its colour is a deep purplish-red, it is opaque, has a compact splintery fracture resembling a coarse jasper. It gives sparks when struck against a piece of steel, and exhibits a fiery red light by collision. It is extremely hard. Sp. gr. 3.9. It generally contains dispersed through its substance particles of magnetic iron ore.

CREAM OF LIME. When well-burnt lime is slacked by water, it falls into a very fine im-

palpable powder, which, diffused in more water to the consistence of cream, remains for some time suspended in it, and is then called *Cream of Lime*.

CREAM OF TARTAR. This well-known salt is composed of tartareous acid in excess, united with potash. It is therefore accurately defined by the term *Super-tartrate of Potash*. (See *TARTAREOUS Acid*.)

CROCUS OF ANTIMONY is a perfect oxyd of ANTIMONY formed by nitre, and from its yellow colour called *crocus* or *saffron*.

CROCUS OF MARS. This term is given to several yellow oxyds of iron, formed by calcination in a red heat either of the rust of this metal or of sulphat of iron. When finely levigated it is much used for polishing steel and other metals. See *IRON*.

CRYOLITE. *Cryolith*, Karsten. *Alumine fluatée alkaline*, Haüy.

The colour of this mineral is greyish-white; it occurs in mass. Its fracture is lamellar in three directions, giving a rectangular prism for its primitive form. Its lustre when broken in the direction of its laminæ is shining and vitreous: it is considerably translucent, and when immersed in water it becomes semitransparent. Its hardness is inferior to that of fluor spar; when scraped it is of a snow-white colour. Sp. gr. = 2.95.

When exposed to the blowpipe it melts at first with great ease, but after a time becomes covered with a white crust, and it is then more difficult of fusion. It is soluble with effervescence in sulphuric acid, and at the same time gives out fluoric acid vapour. It has been analysed by Klaproth and Vauquelin with the following results.

Fluoric acid and water	40.5	—	47.
Soda	36.	—	32.
Alumine	23.5	—	21.
	100.0		100

The only specimens of cryolite yet known were brought by a missionary from Greenland to Copenhagen, where they lay unnoticed for some years, till being examined by Abildgaard, they were found to contain fluoric acid and alumine. The geological history of this mineral is entirely unknown.

CRUCIBLE. An article of chemical apparatus. (See the *Appendix*.)

CRYSTAL MINERAL or **SAL PRU-
NELLÆ**, is an old preparation in chemical pharmacy, now disused, formed by melting a

pound of nitre and adding thereto as soon as it is red-hot a dram of sulphur. A detonation takes place and sulphuric acid is formed, which unites with that portion of the potash from which it has expelled the nitric acid. It consists therefore of nitre deprived of its water of crystallization, united with a small portion of sulphat of potash.

CRYSTAL Rock. See *QUARTZ*.

CRYSTAL. **CRYSTALLIZATION.**

Ice, on account of the ease with which it is liquefied, was called by the Greeks crystal (*κρυσταλλος*); a term which afterwards came to be applied by the Roman naturalists to the substance at present named rock crystal, because from its colourless transparency, and its being procured among the Alps and other cold mountainous regions it was supposed to be only water indurated by continued frost to a greater degree than common ice, and therefore more permanent. Not only the transparency but the remarkably symmetrical figure of rock-crystal, consisting of a six-sided prism, terminated by a six-sided pyramid, more or less perfect, was noticed with surprise and delight; and as soon as it was observed that nitre and certain other salts were also capable by particular management of exhibiting a similar prismatic form, the term crystal assumed a more general meaning and included all those regular polyhædral transparent solids which are presented to our notice either by nature or chemistry. In this sense the word is employed by the old chemists, and the crystalline form was considered as peculiarly characteristic of saline substances. By degrees it was found that the same tendency to symmetrical arrangement which had been noticed in the class of salts, obtained also in the metallic ores and in a variety of other bodies belonging to the mineral kingdom; and at length some able naturalists and chemists, chiefly of the French school, began to be of opinion that, with the exception of animal and vegetable matter either living or in a state of imperfect decomposition, every solid substance in nature was capable of crystallization. They moreover maintain that each species has a peculiar characteristic form to which all the varieties of crystallization that it exhibits may be reduced, and that all amorphous bodies are mere homogeneous or heterogeneous aggregates, in which the proper specific character is obliterated.

All compound bodies (and it is highly probable that most of those which chemistry is obliged to rank as simple are in fact compound) may be considered as made up of *integral*

particles, each of which is again composed of elementary ones. Thus a mass of muriated soda consists of a vast multitude of little cubes, which are its integrant particles, each of which is resolvable into muriatic acid and soda, which are its elementary particles. With the latter of these crystallization has nothing to do, nor is it possible to ascertain their forms, since they are not decomposable by means which have any relation to form. Thus when a piece of common salt is pounded in a mortar, the concussions that it receives are continually destroying the adhesion between its integrant particles, and though perhaps it is incapable of being actually and completely resolved, on account of the comparative coarseness of the instruments that we are obliged to make use of, yet we see an evident approximation to this, and cannot doubt that a continuance of the same means with more perfect instruments would be completely efficacious. Now a body that is mechanically divisible must be produced by the adhesion or aggregation of its constituent particles, and these, both with regard to their forms and the manner in which they adhere to each other, are proper objects of measurement and mathematical calculation. The case however is widely different with regard to the elementary particles of which the integrant molecules are composed: these are incapable of being in the smallest degree separated by percussion or any kind of mechanical force, and therefore the mode of their combination is not capable of being explained by geometrical calculation.

All the integrant particles of the same substance are of the same figure, and the great varieties that appear in its crystalline forms are owing to the different modes in which its particles are aggregated upon each other. This is evident, because by dividing the most complex crystals in the direction of their laminae, a regular figure called the nucleus or primitive figure will be at length produced, which is further divisible only in a direction parallel to its sides, and the corresponding angles of which in any number of specimens will be found to be strictly equal. But though the nuclei of all crystals belonging to the same species accurately correspond with each other in their form and the dimensions of their angles, yet it is by no means true, as has been hastily asserted, that every species has a peculiar primitive form. Thus boracite, muriat of soda, galena and iron pyrites have the same primitive form, namely a cube, and the same integrant molecule which is a cube also. In like manner fluor spar, alum,

spinelle ruby, diamond, ruby copper, bismuth and antimony afford by calculation and mechanical division a regular octohedron for their primitive figure, composed of regular tetrahedral integrant particles. With the exception however of these nuclei, which are regular geometrical solids, and therefore unsusceptible of any variety in their dimensions, it may be affirmed that no two nuclei of different species have precisely the same dimensions; thus the primitive form both of calcareous spar and tourmaline is an obtuse rhomboid, but in the former the obtuse angles are $= 101^{\circ} 32'$, while in the latter they are $= 113^{\circ} 34'$. The primitive forms that have hitherto been observed are the following: 1. the cube; 2. the regular octohedron; 3. the regular tetrahedron; 4. the rhomboidal dodecahedron; 5. the rhomboid; 6. the octohedron composed of two pyramids, with square, rectangular or rhombic bases; 7. the tetrahedral prism either straight or oblique, with square, rectangular or rhombic bases; 8. the regular hexahedral prism; 9. the pyramidal dodecahedron.

It has been the practice of some late authors to extend the meaning of the term crystallization so as to make it synonymous with the attraction of aggregation; this however appears to be injudicious; the latter comprehends every species of formation by which solids are produced, but the former expresses only that regular arrangement of homogeneous integrant particles by which, when interrupted, crystalline laminae, and when uninterrupted, entire crystals, are produced; aggregation therefore includes crystallization, which is only a mode or species of the former. It is of importance to bear in mind that not only a regular external figure, but a regular internal structure is necessary to constitute a crystal; otherwise a column of basalt might be considered as a prismatic crystal, an error which some of the older mineralogists have actually fallen into.

The integrant molecules of different substances appear to be possessed of very different degrees of crystalline polarity; the relative force of which may be estimated in some measure from the comparative quantity of extraneous matter with which they may be intimately mixed without annulling their power of crystallization, and partly also from the proportion which crystals of any species bear to the uncrystallized masses of the same. For this reason carbonat of lime may be considered as endowed with a high degree of crystalline polarity, for not only are crystals of this substance exceedingly abundant

but they occur with all the geometrical characters of calcareous spar, even when mixed with a very large portion of foreign ingredients. Thus the acute rhomboids of calcareous spar which are found at Fontainebleau, contain more than two-thirds of their weight of granular quartz: the primitive figure and crystalline varieties of pearl spar are precisely those of calcareous spar, although, in many instances, the carbonat of lime in this mineral amounts to no more than about a third of its weight, the remainder being oxyd of iron and manganese; again in the bitter-spath the carbonat of lime preserves its essential crystalline character though mixed with nearly half its weight of carbonated magnesia. On the other hand, the crystalline polarity of sulphuret of copper is probably but small, on account of the minuteness of its crystals, and their comparative rarity.

Hardly any of the crystallizations that are performed by nature have been imitated by art; in return, however, chemistry has been able to effect the crystallization of a variety of substances, chiefly salts, which are not found crystallized naturally; and by taking proper advantage of this circumstance has succeeded in obtaining them in a state of greater purity than any other method could afford them.

All substances in order to be crystallized require that their integrant molecules should be separated from each other by the intervention of a medium in which they may move freely according to the attraction of their crystalline polarity. But this necessarily implies two distinct operations; for the same attraction exerted by the medium or solvent to overcome the aggregation of a body, and reduce it to its integrant molecules will also prevent the efficacy of its crystalline polarity. It is necessary therefore after having annulled the aggregation of a solid by the requisite quantity of a solvent, to abstract by degrees such a portion of it that the attraction of the remainder shall be inferior to the crystalline polarity of the substance dissolved. The simplest solvent that can be employed is caloric, and many great advantages attend its exclusive use; a number of cases however occur, in which its application is impracticable, except in combination with some liquid menstruum, as water or alcohol.

Solids that are easily volatilized without decomposition at a moderate temperature, may be obtained in a crystalline state by gradual sublimation in close vessels. Thus when grey oxyd of arsenic is exposed to a low red heat the aggregation of its integrant molecules is destroyed,

and it is converted into a vapour which at the same or any higher temperature would continue in a permanently elastic state. This is the first part of the process, namely the separation from each other of the integrant particles of the arsenic, in consequence of the addition of caloric, which interposes itself between them: the second part of the process, or the formation of crystals depends on the tendency to an equilibrium by which it is characterized, and its being able to pass with readiness through media that are impermeable to other bodies. When, therefore, the vapour, consisting of caloric and oxyd of arsenic, arrives in the upper part of the vessel, the caloric passes through, like water through a filter, while the oxyd of arsenic is left behind; this latter, therefore, is continually increasing in proportion to the remaining caloric, till the crystalline polarity of the particles of arsenic becomes superior to the attraction of the caloric. As soon as this takes place, a stratum of particles begins to be deposited on the inner surface of the containing vessel, and these serve as a basis to which all the succeeding ones attach themselves according to their peculiar mode of arrangement, in proportion as their crystalline attraction becomes superior to the affinity exerted by the caloric. In this way not only are volatilizable substances when unmixed with others obtainable in a pure crystalline state, but they may often be separated hereby from intimate mixture or combination with bodies of greater fixity. Thus benzoic acid is separable in a crystalline form from the resin with which it is naturally combined by taking advantage of its ready volatility at a moderate heat: thus also the manufacturers of sal-ammoniac separate this salt from sulphat of soda, and procure it of a crystalline texture by the application of a degree of heat sufficient to sublime the former, while it has no such action in the latter.

Bodies may be made to assume the crystalline state not only by the process of sublimation but in many cases by a temperature only sufficient to fuse them. If a mass of bismuth is melted in a crucible, and allowed to cool gradually, although its external figure is casual or amorphous, yet its internal texture will be found to be completely lamellar in two or three directions, or crystalline; and if the external lamellæ are successively removed from the surface of a fragment, of the size of a hazle-nut for example, a regular octohedron will at length be obtained which is the primitive form of this metal. Not only the texture but even the crystalline figure of bismuth, may be obtained by fusion with a

little management: the metal being melted in an iron ladle held in a slanting direction, is to be cooled very gradually, and when it begins to consolidate, the ladle being gently and gradually inclined in the opposite direction, the fluid part of the metal will flow off from that which has become fixed, and thus a group of cubical crystals will be obtained. A better way of obtaining crystals of bismuth, as well as of antimony, sulphur, the sulphurets of bismuth and antimony, and some other substances, is to melt a considerable quantity in a crucible, and afterwards to cool it as slowly as possible, till a thin crust has formed upon the surface, two small opposite apertures being then made through the crust with a pointed iron, the fluid portion is to be quickly poured out by one opening while the air enters by the other: when the crucible with its contents is grown cold, the crust is to be carefully removed by a chisel or other suitable instrument, and a cup-shaped hollow will present itself studded with crystals more or less perfect according to the magnitude of the original mass, the slowness with which it has cooled, and the dexterity with which the fluid part has been evacuated.

There are, however, but few chemical substances, comparatively, that can be obtained in a crystalline state by the agency of heat alone; for some are decomposable by fire, and others are either infusible or require such a high temperature for this purpose as to make its application exceedingly troublesome and inconvenient. In effecting the crystallization of nearly the whole of the compound salts and a few other bodies, recourse has been had to the agency principally of water and alcohol, as these two fluids exert a considerable solvent power on the substances exposed to their action, without however decomposing them; and being themselves readily volatile at a moderate temperature, they may be abstracted with sufficient slowness to allow the substances held by them in solution to be deposited in a crystalline form.

When a mass of salt, nitre for example, is immersed in water of the common temperature, the cohesive attraction of its particles is opposed by the solvent power or chemical attraction of the water. At first, the nitre, being surrounded on all sides by particles of uncombined water, begins to be rapidly dissolved; but as the solution proceeds, this effect becomes more and more languid, till at length it entirely ceases, when the number of uncombined particles of water is so far reduced that the sum of the solvent forces of those which are in contact

with the nitre, exactly counterbalances the attraction of cohesion by which the undissolved residue of the nitre is held together. When this state of equilibrium takes place the solution is said to be saturated; but although this is the case as long as it undergoes no increase of temperature, yet in proportion as the heat of the water is raised the solvent power of the liquid is greatly augmented. The salt therefore that is contained in boiling hot water may be considered as rendered fluid by the combined action of the heat and water, and if this menstruum is completely saturated, it is manifest that in proportion as it cools the cohesive attraction between the particles of nitre will gain the ascendancy, and continue to act till the opposing forces of the ingredients of the solution find themselves again in equilibrium. All salts therefore which are more soluble in hot than in cold water, are in part deposited from a saturated solution by mere cooling, and if this is done gradually, and without the interference of any materially disturbing cause, the particles as they consolidate will arrange themselves in regular crystals. When a solution of this kind has deposited by cooling, all the saline particles which it was enabled to hold by its increased temperature, in addition to those which were retained by the mere action of the water, it is obvious that recourse must be had to the abstraction of the liquid menstruum itself if we wish to procure from it any additional crystals. We therefore subject the whole to a boiling heat which has the double advantage of driving off part of the water, and enabling the remainder in consequence of the increased temperature still to hold the salt in solution. When the evaporation has proceeded for some time, a saline pellicle begins to appear on the surface of the liquor, which is a proof that the cohesive attraction of the particles of the salt is obtaining a superiority over the solvent power of the hot water, and by continuing the evaporation the whole of the water will be driven off, and the salt deposited in an amorphous uncrystallized mass: but if when the pellicle appears the solution is slowly cooled, it will deposit, as at first, in a crystalline state all that portion of salt which in the cold saturated solution was combined with the water that has been evaporated. Thus by successive evaporation and gradual cooling all substances capable of crystallizing, and which are more soluble in hot than in cold water, may be procured in their proper crystalline forms.

A few salts, especially muriat of soda, are

nearly equally soluble in water of any temperature, these therefore can only be obtained in a crystalline state by evaporation, and to succeed completely requires considerable management. If the solution is made to boil the evaporation it is true goes on rapidly, but the commotion thus occasioned in the liquor prevents that orderly deposition of the saline particles which is absolutely requisite in order to obtain large and well formed crystals: neither must the evaporation be very slow otherwise the particles as they separate from the liquors are principally attracted to the sides of the vessel up which they ascend, thus lining the upper part of it with an amorphous crust, while hardly any crystals are deposited at the bottom of the vessel.

All crystals that are formed in water return a portion of this fluid, which is called the *water of crystallization*. Its proportion varies according to the nature of the salt that is crystallized, and appears to be in an inverse ratio to the force of its crystalline polarity. Thus sulphat of potash, which requires a large quantity of water to counterbalance the cohesive force of its particles contains but little water of crystallization, whereas sulphat of soda which is readily soluble in water, holds more than half its weight of water. This water appears to be in a state of chemical combination with the salt, and not simply interposed between its crystalline laminae; the affinity however which it exerts is but feeble, at least in those salts into the composition of which it enters largely, since a considerable proportion of it is driven off by simple exposure to the air. In these cases the crystal moulders away to powder, and entirely loses its peculiar figure and texture; hence it has been argued that this water is essential to the figure of all the salts in which it exists: in some degree no doubt it is, for if the water is hastily driven off, the texture of the crystal is entirely destroyed, and there are no facts as yet observed to prove the possibility of the earthy sulphats assuming a crystalline form by any other medium than water, yet the following fact seems to show that the *form* of the crystal is not liable to be greatly modified by the water of crystallization. If a number of cubes of common salt, produced by evaporation in the usual manner, are placed in a covered vessel over the fire, as soon as they become heated they decrepitate, or fly to pieces with a crackling noise on account of the evaporation of their water of crystallization: when this noise ceases the water is driven off, and the salt has lost its cubic shape and crystalline texture, and is reduced to a fine white powder:

by augmenting the heat this powder enters into fusion, and when cooled slowly exhibits again its crystalline texture, and breaks into cubical fragments in the same manner as before it was heated.

If a crystallizable salt is perfectly pure, its solution will continue to afford crystals by the common treatment to the very last drop: but as all salts have a greater or less chemical action on each other, it usually happens when two or more coexist in the same solution, that after crystals have been obtained by successive evaporations and coolings, the remaining portion of fluid, though charged to saturation with saline matter, refuses to yield any more crystals. This liquor, whatever may be the nature of its contents, is known by the general appellation of *Mother water*. Those salts, the crystals of which are permanent in the air, have the strongest degree of crystalline polarity; in those which are efflorescent this force is considerably less, but it is the weakest of all in those that deliquesce on exposure to the air. Now if two salts of the first class are dissolved together in the same quantity of water, provided they do not decompose each other, and especially if their ratios of solubility are different, although they are rendered more soluble by their mutual affinity, yet they may be obtained again in a crystalline state without leaving any mother water. Thus equal parts of nitrat of potash and sulphat of potash, though soluble when mixed together in less water than would have been necessary for both separate, afford by evaporation successively and in proportion to their solubility, first, sulphat of potash, and then nitrat of potash, without leaving any uncrystallizable liquid. But on the other hand if nitrat of soda and sulphat of soda are subjected to the same experiment, both of which have only a slight tendency to crystallize and are of nearly equal solubility, only a small quantity of sulphat of soda will separate by crystallization, all the nitrat and the remainder of the sulphat remaining liquid and uncrystallizable. When the mutual action of the two salts is sufficient to effect a double decomposition of them, it is necessary to take into consideration the solubility of the new salts, in order to make a correct estimate of the quantity of uncrystallizable residue. Thus if equal parts of sulphat of magnesia and muriat of soda are mixed together, although the ratio of solubility of the two is different, and their force of crystallization is also considerable, yet the liquor can hardly be made to yield any crystals at all; for in consequence of

a mutual decomposition, muriat of magnesia a deliquescent salt, and sulphat of soda an efflorescent one, will be formed, and the slight crystalline force of the latter will be almost wholly annulled by the extreme solubility of the former.

It has been already mentioned that the disturbance occasioned by ebullition and other causes of agitation prevents the formation of regular crystals: the converse however of this is not true, namely that the entire absence of external motion is peculiarly favourable to regular crystallization. The solutions of those salts that are much more soluble in hot than in cold water, and have but a feeble power of crystalline polarity may, if kept still, be cooled by degrees considerably below their congealing or crystallizing point, and still retain their fluidity; apparently, because the attraction of their particles, in itself feeble, and opposed by the affinity of the water, is held in equilibrium because no one particle has a preponderating power over those in its vicinity; for if a piece of the same kind of salt that is contained in the solution be introduced even with the utmost precaution, the superior attraction of the mass will be immediately exerted on the neighbouring particles, and a rapid growth of crystals will take place, radiating from this mass as their centre of attraction. Crystallization may also be induced in similar circumstances merely by agitation, but when this is the case it is always confused and irregular.

For further particulars connected with this subject see AFFINITY, SOLUTION, PRECIPITATION.

CUCURBIT is an article of chemical apparatus. (See the Appendix.)

CULM. See COAL.

CUPEL is a small crucible used in the process of cupellation.

CUPELLATION. *Abtreiben*, Germ. This important process in metallurgic chemistry is described at length under the article ASSAY.

CURCUMA. See TURMERIC.

CYANITE. *Kyanit*, Werner. *Sappare*, Saussure. *Disthene*, Haüy.

Its colour is milk-white, pearl-grey, bluish-grey, or smalt-blue, Prussian blue or sky-blue. It sometimes occurs entirely blue, but more

frequently spotted, striped or clouded with this colour. It is found in mass, disseminated, and crystallized in long oblique four-sided prisms, truncated on the lateral edges. The crystals are imbedded or intersect one another, and vary from middle-sized to very small. Its external and internal lustre is bright-shining pearly. Its fracture is broad diverging and intersecting radiated, passing into curved-foliated. The fracture of the crystals is foliated in three directions. Its fragments are flaty and sometimes imperfectly rhomboidal. In mass it is usually translucent; the crystals are for the most part transparent. Its hardness is about equal to that of fluor spar. It has a slight degree of flexibility, and feels somewhat greasy. Sp. gr. 3.51 to 3.62.

It is infusible *per se* before the blowpipe. Its component parts, according to Theodore de Saussure, are

29.2	Silex,
55.	Alumine,
2.25	Lime,
2.	Magnesia,
6.65	Oxyd of iron,
6.9	Water and loss.

100.00

It occurs in primitive mountains imbedded in micaceous schistus and accompanied by garnetite.

It is found near Banchory in Aberdeenshire, and in the largest of the Shetland islands; also in Norway, the Swiss Alps, the Pyrennees, the Tyrol, Carinthia, Bavaria, France and Siberia.

The very pale varieties of this mineral are sometimes mistaken for tremolite; it may be distinguished however by the blue tinge which even the palest are not entirely free from: besides tremolite is found chiefly in granular limestone, but cyanite in micaceous schistus. The transparent varieties of a Prussian blue colour are sometimes when cut and polished sold for sapphires, from which however they are readily distinguished by their inferior hardness and specific gravity.

CYMOPHANE. See CHRYSOBERYL.

• Haüy, Brochant, Emmerling, Jameson.

D

DAOURITE. See SCHORL.

DECOCTION. *Abkochen-Absieden*, Germ.

Is the extraction of the soluble part of any substance by means of boiling, generally with plain water. Decoction is one of the simplest and most efficacious methods employed in the analysis of vegetable and animal matters. It is also largely used in pharmacy.

DECOMPOSITION. *Zersetzung*, Germ. Most of the processes in chemistry are attended with the disunion of substances already joined together, or decomposition, and the consequent formation of new compounds. In the Appendix will be given most of the known decompositions produced by the mixture of the common chemical substances.

DECREPITATION. *Decrepitiren-Abknistern*, Germ.

When hard crystals of any saline substance containing but little water of crystallization are heated suddenly, they do not liquefy as the watery salts do, but crack and fly in pieces with vehemence, owing to the escape of the water, which is called *decrepitation*. Common salt affords a familiar example of this, and for convenience when used as a flux in the reduction of minerals it should be previously decrepitated.

DEFLAGRATION. This term expresses a gradual sparkling combustion of any substance without violent explosion. It is particularly applied to many instances of combustion produced by nitre.

DELIQUESCENT. *Zerfließen*, Germ.

Is the spontaneous liquefaction of any salt by simple exposure to air. Potash is an example of the kind. As the deliquescent salts absorb moisture from the air they are of use in rendering air dry, which is often required for nice experiments.

DEMANTSPATH. See CORUNDUM.

DEPHLEGMATION. *Entwässern*, Germ.

Is the depriving any liquid of part of the superfluous water which it may contain, and thus it has the effect of concentration. Thus sulphuric acid is dephlegmated by boiling for a time, which expels at first little else than mere water. Vinegar is dephlegmated by partial freezing, the ice that first forms being only the watery portion containing none of the acid.

DEPHLOGISTICATED AIR. See OXYGEN.

DEPHLOGISTICATED MARINE ACID.

See OXYMURIATIC ACID.

DEPHLOGISTICATED NITROUS AIR.

See NITROUS OXYD.

DERBYSHIRE SPAR. See FLUOR SPAR.

DESICCATION is the complete drying of any substance.

DETONATION. *Verpuffen*, Germ.

Is explosion accompanied with loud noise. A sudden evolution of light attends most instances of detonation. *Fulmination* has a similar meaning.

DIAMOND. *Demant* Werner; *Diamant* Haüy and Broch.

The diamond is either colourless, or of a light yellow, or smoky-grey passing into bluish, or pearl grey, or clear wine colour, on one hand deepening into clove brown, and passing on the other into yellowish green: it also occurs of a deep almost black brown, prussian blue or rose red. The colourless varieties are the most esteemed, and are perhaps the most frequent; next to these in value are the black, blue, and red, they are also by far the rarest, the light coloured are in the least estimation.

It is found crystallized in the regular octohedron (which is its primitive form) composed of two four-sided pyramids applied base to base. Sometimes each triangular facet of the primitive octohedron is replaced by six secondary triangles bounded by curvilinear lines, in which case the whole crystal has forty-eight facets, and is of a spheroidal figure. Other spheroidal varieties of this mineral are the dodecahedron, a solid of 24 facets, and a compressed spheroid resembling a very short six-sided prism, terminated by very short curvilinear pyramids. Sometimes the pyramids of the octohedron, instead of ending in a point terminate in a line, whence results a rhomboidal quadrangular prism with dihedral summits.

The surface of the regular octohedrons is generally smooth and shining, that of the other varieties is somewhat dull and rough; but internally, especially when cut and polished, they are all of extreme brilliancy, far surpassing both in lustre and lively play of prismatic colours every other substance. Rough diamonds are usually covered with a very thin crust, which renders them semi-transparent, but when this is removed they are transparent, though

somewhat inferior in this respect to rock crystal. The fracture of diamond is strait foliated, its lamellæ being parallel to the sides of a regular octohedron. Its hardness is superior to that of all other bodies natural or artificial, it yields however to corundum by long continued friction. It is brittle, and not difficultly frangible. Sp. gr. 3.518—3.550.

Diamond, even when rough, acquires, by friction, the vitreous or positive electricity. It becomes phosphorescent when exposed either to the entire rays of the sun, or to the blue ones alone when separated by the prism, and concentrated on the diamond by means of a lens: a similar effect is also produced by fixing it to the end of a charged conductor, and taking a few electric sparks from it. Many diamonds however are incapable of becoming phosphorescent, although agreeing in colour, transparency, &c. with those which readily become luminous. Those which are small acquire this property by a much shorter exposure to the light than the larger ones: sometimes a diamond that is not phosphorescent by the simple action of the solar light, may be made so by previously immersing it for some time in melted borax.^b

Diamond when exposed to a current of air, and heated to the temperature of melting copper, is gradually but completely combustible, and is surrounded, during the process, by a luminous areola. It is wholly converted into carbonic acid, and therefore consists of pure carbon, as we have already mentioned under that article.

The art of cutting and polishing diamonds was probably known to the inhabitants of Hindostan and China at a very early period; the only material however that is used in the East for this purpose, being corundum, and the apparatus being of extreme simplicity, the jewellers of these countries are incapable of bringing out the peculiar beauty of the diamond in a degree at all comparable to what is readily effected by European artists. The extreme hardness of this gem had baffled the attempts of the jewellers of Europe till the year 1456, when a young man named Louis de Berquin, a native of Bruges, endeavoured to polish two diamonds by rubbing them against each other; he found that by this means a facet was produced on the surface of the diamonds, and in consequence of this hint, constructed a polishing wheel, on which, by means of diamond powder, he was enabled to cut and polish this substance in the same manner as other gems are wrought by emery. Previous

to this discovery, diamonds were set in jewellery precisely in the state in which they arrived from India, and hence the regular octohedrons were much more esteemed than the rest, both on account of the regularity of the figure, and the superiority of its natural polish.

Diamonds are cut and manufactured by jewellers^c into brilliants and rose diamonds; the former being for the most part made out of the octohedral crystals, and the latter from the spheroidal varieties. To fashion a rough diamond into a brilliant the first step is to modify the faces of the original octohedron, so that the plane formed by the junction of the two pyramids shall be an exact square, and the axis of the crystal, or a line connecting the apices of the pyramids, and perpendicular to this common base, shall be precisely twice the length of one of the sides of the square. The octohedron being thus rectified, a section is to be made parallel to the common base or *girdle*, so as to cut off $\frac{5}{8}$ of the whole height from the upper pyramid and $\frac{1}{8}$ from the lower one: the superior and larger plane thus produced is called the *Table*, and the inferior and smaller one is named the *Collet*: in this state it is called a *complete square table diamond*. To convert it into a brilliant, two triangular facets are placed on each side of the table, thus converting it from a square to an octagon, a lozenge-shaped facet is also placed at each of the four corners of the table, and another lozenge extending lengthways along the whole of each side of the original square of the table, which, with two triangular facets set on the base of each lozenge, completes the whole number of facets on the table side of the diamond, viz. eight lozenges and twenty-four triangles: on the collet side are formed four irregular pentagons alternating with as many irregular lozenges, radiating from the collet as a centre, and bordered by sixteen triangular facets adjoining the girdle. The brilliant being thus completed is set with the table side upwards, and the collet side implanted in the cavity made to receive the diamond. The regular rose diamond is formed by inscribing a regular octagon in the centre of the table side of the stone, and bordering it by eight right angled triangles, the bases of which correspond with the sides of the octagon; beyond these is a chain of eight trapeziums, and another of sixteen triangles. The collet side consists also of a minute central octagon, from every angle of which proceeds a ray to the edge of the girdle, forming the whole surface into eight trapeziums,

^b Groffer in Journ. de Phys. xx. p. 270. ^c Jeffries on Diamonds, p. 9.

each of which is again subdivided by a salient angle, the apex of which touches the girdle, into one irregular pentagon and two triangles. In the formation of either a brilliant or rose diamond of regular proportions, so much is cut away that the weight of the polished gem is no more than half that of the rough crystal out of which it was formed, whence the value of a cut diamond is esteemed equal to that of a similar rough diamond of twice the weight, exclusive of the value of the workmanship. The weight, and consequently the value of diamonds, is estimated in carats, 150 of which are equivalent to 240 grains or 1 oz. Troy, and the difference between the cost of one diamond and another, *ceteris paribus* is as the squares of their respective weights. Thus the value of three diamonds of one, two, and three carats weight respectively, is as one, four, and nine. The average price of rough diamonds, that are worth working, is about 2 pounds sterling for the first carat, and consequently in wrought diamonds, exclusive of the cost of workmanship, the cost of the first carat is = 81. Hence a wrought diamond of

5 carats is worth	£ 200
10 ditto —	800
20 ditto —	3,200
30 ditto —	7,200
40 ditto —	12,800
50 ditto —	20,000
60 ditto —	28,800
70 ditto —	39,200
80 ditto —	51,200
90 ditto —	64,800
100 ditto —	80,000

This rule however actually holds good only in the smaller diamonds of twenty carats and under, the larger ones, in consequence of the scarcity of purchasers, being disposed of at prices greatly inferior to their estimated worth. The largest diamond at present known is in the possession of the Emperor of Russia, it weighs 779 carats. The Pitt or Regent Diamond, the finest of the crown jewels of France, weighs 136 carats, and was purchased for 2,500,000 livres.

The mineralogical situation of the diamond is not well ascertained: it occurs in India in detached crystals, in a kind of indurated ochery gravel, but whether or not this is its native bed is unknown. The diamond mines of India are dispersed throughout the whole chain of the Ghauts from Bengal to Cape Comorin; many

of these are however at present abandoned, the chief that are now worked being situated between Golconda and Mazulipatam. The earth which affords them being dug up and broken to pieces is carefully washed till the water comes off colourless, and the residue is spread thin on mats in the sun, where the diamonds are discovered by their superior brilliancy.^d This valuable gem is also procured from Borneo and from Brazil in the mountainous district called Serro Dofrio contained in alluvial beds of ferruginous sand.^e

The principal use of diamond is in ornamental jewellery; it is also employed by glaziers and lapidaries to cut glass, and engrave upon the harder gems; and in the finer kinds of clockwork.

DIAPHORETIC Antimony is a perfect oxyd of this metal made by deflagration with nitre. See **ANTIMONY**.

DIGESTER is an article of chemical apparatus. (See the Appendix.)

DIGESTION. *Digeriren*, Germ. Is the long continued exposure of a substance to the action of any menstruum kept at a nearly uniform temperature, generally above that of the common atmosphere.

DIGESTIVE Salt is the old term for **ACETITE of Potash**.

DIPPEL's OIL, so called from the inventor, is the oil that rises during the distillation of bone or horn, highly rectified by subsequent and repeated distillation. See **BONE**.

DIPYRE.^a

The colour of this mineral is greyish or reddish white, passing into pale rose colour. It occurs either disseminated in small fascicular masses, or in minute prismatic crystals. It has a brilliant vitreous lustre, a lamellar fracture parallel to the sides of a regular hexahedron. It is moderately hard, easily frangible. Sp. gr. = 2.63.

It is fusible with ebullition before the blow-pipe, and contains according to Vauquelin,

60	Silex
24	Alumine
10	Lime
2	Water

96
3 Loss

100

When pulverized and thrown on a hot coal

^a Phil. Trans. xii. p. 907.

^e Andrada in An. de Chim. xv. p. 82.

^d Brochant, ii. p. 508.

it gives a pale phosphoric light. It occurs at Mauleon in the Pyrennees, imbedded in steatite.

DISTHENE. See **CYANITE**.

DISTILLATION. *Destilliren*, Germ. Is the process of evaporation performed in vessels adapted to condense or collect the substance evaporated.

Distillation in the large way is usually carried on in an apparatus composed of three parts, namely, the alembic or boiler in which the substance is heated; the head or capital, a dome-shaped continuation of the former in which the vapours are collected, and a tube or worm spirally disposed and passing through a tub of water, in which the distilled vapour is condensed into a liquid. For smaller purposes this apparatus is often simplified, and the capital is enclosed in a case which holds cold water, whereby the condensation takes place in the capital itself.

Another apparatus more usual in experiments is a retort, generally of glass, which answers the purpose both of boiler and capital, and a globe-shaped receiver fitting to the retort in which the condensation is completed. The greatest improvement perhaps ever made to chemical apparatus is the (comparatively) modern addition of a separate series of tubes and vessels to convey and collect the gaseous products, and to avoid all the danger from sudden expansion without incurring the necessity (formerly required) of letting off to waste a large portion of the difficultly condensable, but often most important, products of the operation.

The practical uses of distillation in chemistry are too numerous to be mentioned. By it the volatile part of any substance is separated from that which is fixed, as in the distillation of turpentine, in which the essential oil rises and the rosin is left behind: the more evaporable is separated from the less evaporable, as in the preparation or rectification of ardent spirit; liquids are freed from foreign or accidental impurities, as in the distillation of common water: volatile substances are united in an easy and commodious manner, as in preparing the odorous distilled waters of aromatic vegetables: bodies are decomposed and analyzed, new compounds are formed, and a knowledge is gained of the native and chemical properties of natural substances.

When the products of distillation are solid and dry, the process is usually termed *sublimation*.

The apparatus for the different processes will be described in the Appendix.

DISTILLED WATERS. On this large class of chemical preparations, but almost entirely devoted to pharmacy, a few observations may be made.

The object of them all is to impregnate water solely with the aromatic or flavouring principles of plants or parts of plants, leaving behind all the other soluble matter. There is every reason to believe that the substance which flavours the distilled waters of vegetables is essential oil, because in most instances a portion of essential oil actually separates from the water when recently distilled, because the sensible properties of the water are nearly the same as when a few drops of the essential oil of the plant are mixed with pure water by simple agitation, because in the process of distillation the condensed liquor becomes gradually less and less flavoured in proportion as the essential oil must escape, and because distilled waters evaporated to dryness leave no sensible portion of residue.

Common distillation of aromatic vegetables is a simple process, but gives room for some nicety of management, particularly in the regulation of the heat and the quantity of water, which can only be learnt by experience. As an example common peppermint water may be given, and is thus made. Put a pound and a half of dry peppermint in a still, cover it with water, put on the capital, luting the joints with wet bladder or pasted paper, bring the liquor to boil quickly, and keep it just boiling till about a gallon of water has run over. The residue in the still is then thrown away as useless. The water that comes over first is somewhat turbid owing to the excess of essential oil that it contains, and in consequence is by much the strongest. By rest it becomes clear, and a fine pellicle of oil rises to the top.

The following circumstances are chiefly observable in common distillation.

The substance from which the distillation is made in some cases requires previous treatment, in others none. The petals of flowers, such as roses or jasmine, may be used immediately or only after the gentlest drying. The aromatic herbaceous vegetables, such as peppermint, may be used indiscriminately fresh or dry, observing that as the plant is much more watery when fresh than when dry, more water may be added in the distillation of the latter than of the former. Hard woods should be rasped or bruised, and as they are less easily penetrated by the water they should be macerated in it without heat for from one or two days to as many weeks, before distillation.

The quantity of water to be used varies much according to circumstances. It should be always so much as during the whole process to cover all that part of the still which is immediately over the fire, otherwise the vegetable matter will scorch and give a very disagreeable burnt taste and smell, or *empyreuma*, to the distilled liquor. On the other hand too much water makes the distilled liquor unnecessarily dilute. In general, fresh vegetables require about thrice their weight of water, and when dry five or six times. The still should never be more than about three-fourths full, or even less when succulent vegetables are used, to prevent boiling over.

The management of the fire is of some consequence, to prevent boiling over and *empyreuma* on the one hand, and on the other to give heat enough for extraction of the aromatic principle. Where a water bath is used (which however is tedious and seldom if ever necessary) all danger of excess of heat is avoided, but it is often requisite to encrease the heat of the bath by adding salt to the water. When in distilling without a bath too much heat is used, there is danger either of blowing off the capital not without risk to the by-stander, when the liquor boils with extreme vehemence (which is particularly likely to occur when the still is too full of bulky herbaceous vegetables that rise in the capital and partly choke up the opening into the worm-pipe) or else the liquor boils over into the worm-pipe, and mixes a *decoction* of the vegetable with the distilled water. This is soon perceived by the condensed liquor coming out at the bottom of the worm, not in a clear uniform streamlet, but by gushes and starts with a gurgling noise, and fouled or coloured. When this accident happens, the fire should be entirely slackened, the capital taken off, the liquor already come over returned into the still, and the distillation begun again with more care. When the stream of distilled water flows evenly, and the boiling liquor is heard to simmer moderately in the boiler the operator will know that the process is going on properly.

The quantity of aromatic water to be obtained from a given weight of any vegetable cannot be laid down with accuracy, so as to obtain a liquor of uniform strength as (independently of any difference in conducting the operation) the season of year, the length of drying, and other causes, will materially affect the intensity of aroma in the vegetable. The taste therefore is a better criterion to judge when to stop

the process, as the liquor will run nearly tasteless long before the water has all boiled away. Some advantage is gained by mixing all the distilled liquor together, as the first portion has generally rather more essential oil than it can retain, and the last portion has less.

Some other observations relative to the management of distillation will be mentioned under the article of *Oils Essential*, which are mostly obtained by the same process.

Distilled waters are generally supposed to be made much stronger by *cohobation*, or redistilling the same water from fresh materials. No very accurate experiments have been made on this subject, and it would appear that when water is the first time so supersaturated with essential oil as to let go a portion by mere subsidence, no further process can make it take up more. If so great an encrease of sensible and other properties is really produced by cohobation as is usually allowed, it would render probable the old opinion of a *spiritus rector*, or a peculiar principle in which the active and odorant particles reside, separated from, and independent of the essential oil, and which is most largely disengaged at the first impression of heat, and soluble in water already saturated with essential oil.

Some pains have been taken by chemists to examine the properties of the distilled water of *inodorous* vegetables, and to endeavour to bestow on it some medicinal qualities. The water distilled from these differs from common distilled water in possessing a faint and fugitive smell, in growing mouldy by keeping, especially when exposed to the air, and when a large quantity is evaporated, a minute portion of coloured extractive matter is left. This is found to contain a little nitre.^a The distilled water of those plants which have at the same time very active medicinal powers, and very feeble sensible qualities of smell or taste (such as the *digitalis*) deserves further examination.

The greater number of those liquors commonly called *Distilled Waters*, *Cordial Waters* (such as of aniseed, juniper, &c.) are prepared by the particular vegetable distilled with ardent spirit, more or less diluted, and belong to the subject of *distilled SPIRITS*.

DIURETIC Salt. See ACETITE of Potash.

DOCIMASIA, or *Docimastic Art* is applied to that part of chemistry which relates to the analysis of minerals, and all operations in metallurgy.

^a Delunel, An. Ch. tom. 38.

DOLOMITE^a. *Chaux carbonatée aluminifère* Haüy.

Its colour is white with a slight tinge of grey or yellow. It occurs in mass or foliated; its lustre is glimmering, between pearly and vitreous: its texture is fine-granular; its fracture is compact uneven, passing into imperfectly lamellar. It breaks into irregular blunt-edged fragments. It is translucent on the edges, may be scratched by fluor-spar, and is often more or less friable between the fingers. Sp. gr. = 2.8. It is for the most part phosphorescent in the dark by percussion.

It is soluble in nitric acid slowly, and with but little effervescence. Its constituent parts according to Vauquelin^b are

Carbonated Lime	52
Carbonated Magnesia	46.5
Oxyd of Iron	0.5
—— Manganese	0.25
	99.25

It is found in various parts of the Alps, in beds alternating with micaceous schistus, and containing tremolite, orpiment, and cupreous pyrites.

The first analysis of this substance was made by Theod. Saussure, according to whom it consisted of about 88 per cent. of lime with an excess of carbonic acid, between 5 and 6 per cent. of alumine, and the rest magnesia and oxyd of iron: this however has been shown by Vauquelin to be wholly erroneous, and the dolomite will, no doubt, for the future, be considered as the massive variety of Bitterspath, which see.

DOVE is a part of several chemical *Furnaces*. (See the Appendix.)

DRAGON'S BLOOD. (*Sanguis Draconis*), is a resin that exudes from the bark of the *Pterocarpus Draco*, a large tree found in South America, and also from other vegetables, particularly the *Calamus Rotang* found abundantly in many parts of the East Indies.

The resin called dragon's blood is brought over sometimes in oblong pieces about the size of a small walnut, and sometimes in cakes. When good, it is uniform in texture, without smell or taste; breaks smooth and easily; has a very deep blood-red colour in mass, which lightens to a fine crimson when powdered, and readily burns when put to a candle with much flame, and a slight fragrant smell like styrax. Dragon's blood when genuine is nearly if not absolutely insoluble in water, but readily dissolves

in alcohol, giving it a very intense red colour. Water makes this solution turbid. This resin is in some degree soluble in fixed oils, giving them a dull red colour.

Dragon's blood is used pretty considerably in many coloured varnishes and lacquers, often to give a mahogany colour to white wood, or when mixed in small portion with the gamboge yellow it much improves the tint, rendering it deeper and richer. It is a little employed in medicine.

DRYING Oil is oil prepared by boiling with litharge, and is the basis of a vast number of paints and varnishes. See *Oils Fixed*.

DUCTILITY. *Geschmeidigkeit*, Germ. This term is applied to express that extensibility and cohesion of particles which enables a metal to be drawn out into wire without breaking. There is but a slight shade of difference between this property and that of malleability.

DULCIFICATION. *Versüßung*, Germ. Is a term not very accurately defined, and little used. It is generally employed to express the rendering mild, or diminishing the corrosive qualities of acids or alkalies by uniting them with some other substance, but not so as to neutralize them. Thus alkalies might be said to be dulcified when converted into soap; and the strong acids are actually said to be *dulcified* when chemically combined with spirit of wine. Thus we have dulcified spirits of vitriol, dulcified spirit of nitre, &c.

DYEING. *The Art of*. *L'Art de la Teinture*, Fr. *Farbekunst*, Germ.

The object of this ancient and truly chemical art is to fix uniformly, and more or less permanently, certain colouring matters into the fibres of wool, linen, cotton, silk, and other filamentous substances.

The first explanation offered of the theory of dyeing was purely mechanical. According to Hellot, an excellent observer and an acute reasoner, the saline substances employed in dyeing serve to open and enlarge the pores of the fibres to be dyed, the colouring matter is then deposited in these pores, after which, the natural elasticity of the fibre returning, shuts in the particles of colouring matter, and the salts solidifying over them serve as a kind of cement to keep them in their place.^a

Many and insuperable objections however have been brought against this and similar mechanical theories of dyeing, which it is not necessary here to detail.

It is particularly incompetent to explain the great difference between animal and vegetable

^a Haüy.

^b Journ. des Mines, xvi. p. 77.

^c Mem. de l'Acad. 1740 and 1741.

matter in absorbing and retaining colour, and the use of mordants or intermedes as a bond of union between the colour and the fibre to be dyed. Bergman appears to have been the first whose eminent sagacity suggested the idea that chemical affinity was the great agent in these operations, and every subsequent research more and more confirms this opinion.

A detailed account of all the processes of dyeing would of itself fill a volume: in this place therefore all that can be done will be to give a very short view of the leading facts and operations, particularly as connected with general chemistry, and refer the reader to some of the most valuable written documents, particularly to Berthollet's admirably scientific and philosophical view of the subject.^b

The substances commonly dyed are either of animal or vegetable origin. To the former belong wool, silk, hair, leather, and skin of all kinds; to the latter, cotton, flax and hemp. The particular chemical analysis and properties of these substances, as far as they have been examined, will be described under the respective articles. A most important and essential difference exists between the affinity for colouring matter possessed by these substances, so that a process which perfectly succeeds in dyeing wool (for example) may have no effect upon cotton, neither is there any agreement in the quantity of colouring ingredient necessary to dye each stuff.

A simple experiment of Dufay's proves this. He had a piece of cloth woven, of which the warp was wool and the woof cotton, this was fulled that each substance might undergo exactly the same preparation, and then passed through a scarlet vat. The wool only took the colour, but the cotton remained white after rinsing. With regard to quantity of colour, it is found that silk takes twice as much cochineal to dye it as wool does. The different force of affinity between different fibres and colouring matter is also shewn by the more or less perfect manner in which they exhaust a coloured bath; thus, as Bergman observes, wool dyed in a weak solution of sulphat of indigo entirely absorbs the dye and leaves the solution colourless, whereas silk can only partially rob the sulphuric acid of the colouring matter. Generally speaking, wool has the strongest affinity for colour, taking it more easily, and retaining it more firmly; silk and other animal matters come next to wool, cotton next, and hemp and flax last; but this is to be understood with great latitude, nor does it always happen that substances which take colour

the easiest, retain it the longest, besides that the previous preparation is not the same, and hence the comparison is not altogether accurate.

No exact explanation can be given of the different affinity for colour in different substances, except that the analysis of vegetable and animal matters shews a most essential difference in their component parts, and their habits with chemical reagents. It is on this account too that the preparation which each substance receives previously to being dyed so much varies. Animal matter, especially wool, when immersed in caustic alkali has its fibre immediately relaxed, becomes clammy, loses its natural toughness and elasticity, and at last is entirely dissolved into a soapy compound. Vegetable fibre on the other hand resists alkalis much longer, and is not easily dissolved; and hence in the previous cleansing and fulling of wool, alkalies are scarcely admissible, or must be used with extreme caution, whereas they may be employed with safety in the preparation of cotton and linen. Animal fibre is also much more easily affected by acids.

The simple colours employed in dyeing are chiefly of animal or vegetable origin. The number of possible dyes is almost equal to that of the vegetable or insect tribes on the face of the earth, for almost all of these will make a coloured decoction with water, which is capable of tinging cloth immersed in it. Hence the variety of native dyes from indigenous plants used in different parts of the globe by every nation, savage or civilized. A very few, however, are employed in the regular manufactories of European nations, being such as are obtained in the most abundance from countries where they form valuable articles of commerce, and whose qualities are minutely known by long and accurate observation.

Of the great variety of known dyes, some (though comparatively but few) may be applied to animal or vegetable fibre without any other preparation than that of cleansing the stuff, and immersing it in a decoction or infusion of the dye for a sufficient time. The colouring matter then unites with the fibre of the cloth with a greater or less degree of force, so as sometimes permanently to resist the effect of washing, and the bleaching power of the sun and air, sometimes partially, sometimes scarcely at all. On the other hand the greater number of dyes have naturally only a very feeble affinity for fibre, (though never in the same degree for animal and vegetable) and therefore, when applied without

^b Elements de Teinture, second edit.

addition, they are destroyed very speedily; but the ingenuity of man has discovered that they may be made to unite with fibre much more durably by the intermede of some other substance (generally a salt with an alkaline, earthy, or metallic basis) which possesses a very strong affinity both with fibre and with colouring matter, and hence serves to bind the one to the other. These intermedes are called *Mordants* (a term derived from an erroneous theory now abandoned) and the usual practice is first to steep the cloth or fibre in the mordant, and afterwards in the dye.

The dyes that cannot be fixed into the stuff without mordants may be termed (with Dr. Bancroft) *adjective* colours; those in which mordants are of no use may be called *substantive* colours. Madder is an adjective colour, since it is rendered much more durable by the intermede of alum, or of many other salts than when used alone. Indigo is a substantive colour, since its durability is not encreased by any intermede whatever.

Another important difference in the nature of dyes is in the degree of permanence of tint, which certainly in part depends on the force of affinity with which it unites to the fibre, and partly on the intimate nature of the colouring matter, and its susceptibility of decomposition by light, air, moisture, and also by alkalies, soaps, and other substances employed in the common uses of dyed stuffs. The permanency of colour has no necessary connexion with the mode in which it is united to the substances dyed, for among the substantive as well as the adjective colours some are very permanent, others very fugitive. For example, of the substantive colours (or those which unite as strongly to cloth without, as with mordants) *Indigo* is very permanent, resisting the sun, air, washing with soap, and most chemical agents: the oriental *Henne*, which is a fine orange red, long resists the sun and air, but is altered and destroyed by soap: *Archil*, and other of the purple lichens, is instantly altered by soap, and is soon changed by the light and air, so as only to give a very fugitive but beautiful gloss. Of the adjective colours *Madder* is one of the most permanent that is known, retaining its body of colour (when well applied) under almost every circumstance. *Cochineal* on wool is nearly equally fast or permanent, but on cotton much less so, *Brazil Wood* fades much sooner than the last, whatever mordant be applied.

The selection and right application of mor-

dants is of infinite consequence in dyeing, and it is this subject, with its various modifications that forms the truly scientific part of this beautiful art. Linen or cotton requires a different mordant from wool or silk, some colours adhere only to a particular mordant, the order of application, the strength, and many other smaller circumstances, all of which materially affect the beauty and durability of the colour, and the texture, of the cloth, must be attended to by the artist.

Some simple experiments related by Dr. Bancroft,^c and which are readily repeated, well illustrate the action of mordants. A piece of cotton was impressed with various figures with a mordant of acetited alumine, and when dry was rinsed and cleansed in the usual way of calico printing. It was then dyed in an infusion of saffron and came out uniformly yellow, but on exposure to air the whole became white. Hence it is shewn both that the colouring matter of saffron has no strong affinity with cotton, and that alumine has no power of fixing it, and hence is useless as a mordant. The same piece was then dyed with a decoction of Brazil wood, and the whole came out coloured, but the figures printed with the aluminous solution were of a fine crimson, whereas the ground was only faintly tinged. On exposure to the sun and air for two days the ground soon became white, and the figures also were faded, and in eight days the crimson of the latter, which had been gradually diminishing, was no longer visible. This second experiment shews that acetited alumine is a powerful mordant for Brazil wood, but still not sufficient finally to fix its colour.

The same piece was then dyed with a decoction of madder, and the whole came out coloured, but the figures deeper than the ground. On washing with bran and water, and exposure to sun and air, the ground became white, but the figures retained all their body and brightness of colour, and this time the dye was permanent, shewing in a very striking manner the strong affinity both of the alumine for the cotton so as to remain fixed in its fibres during three successive operations, and of the alumine for the madder colour so as to retain it permanently in spite of the washings and bleaching which entirely destroyed the dye of the ground.

Mordants not only fix colouring matter, but most commonly they in some degree alter the natural hue. Thus in the instance above-mentioned the aluminous mordant changed the dull

* Experimental Researches on permanent Colours.

red of madder to a bright crimson; the solutions of tin not only fix the colour of cochineal in wool, but change it from crimson to a bright scarlet: the salts of iron which are powerful mordants, always alter the colour of dyes, changing the yellow of weld to olive-brown, drab, or lead-colour according to circumstances, the red of madder to a violet brown, and, as is well known, striking a bluish-black whenever the gallic acid is present. Hence a great advantage is most ingeniously made of mixing different kinds of mordants to produce varieties of shade; thus a mixture of the iron and aluminous mordant will produce with madder all the shades of flea-colour, purple and violet; with weld, brown and olive green, and the like, so that with no more than three or four colouring materials an almost infinite variety of dyes may be produced by a due selection and mixture of the various mordants.

Two important and distinct manufactures belong to the subject of dyeing, the one is *dyeing* properly so called, or the art of giving an uniform colour to an entire piece of stuff: the other is topical dyeing, or the art of fixing various coloured patterns on an uniform ground, which, from its being chiefly and originally employed on cotton or calico, is called *Calico-printing*. The basis of each art, as far as relates to the chemical action of the fibres of the stuff upon the different dyes and their mordants, is precisely the same, and in general the materials employed are nearly the same, but the manipulations and particular mode of application widely differ. A few of the principal processes of general dyeing will first be described, after which a short notice will be taken of calico-printing.

The process of dyeing in the piece consists of a few simple operations repeated more or less often according to circumstances, with many minute variations in the temperature, time of immersion, and the like, according to the nature of the stuff and the colour to be given, by rules which experience alone can teach.

The following is a short sketch of the mode of dyeing the principal colours, chiefly taken from Berthollet, Lewis, Bancroft, Hellot, and some other authorities; but it should be added that the variety in the processes actually used is almost endless, almost every manufacturer having his particular receipt, in which slight variations in the quantity or quality of ingredients, the time or order of application and other minute circumstances, are found to render the colour

somewhat more or less full, durable, glossy, uniform, and the like.

Of Blacks.

There are a few native vegetable juices that produce durable *substantive* blacks, or such as can be fixed at once on cloth without any previous preparation. Of this kind is the *Anacardium orientale*, a kind of nut, containing between the inner and outer shell a fungous substance filled with a viscous fluid in small quantity. This juice rubbed on linen and cotton gives a reddish brown stain, which by exposure to air deepens to a full black that is quite permanent. It is said to be used in India for marking linen and cotton cloths, and hence is called the *Marking Nut*. The West India cashew nut is of a similar nature with the East Indian *anacardium*, but the colour is not so deep. The *anacardium* would be highly valuable if it could be collected in quantity, particularly for linen and cotton, but is only used very partially in the countries of which it is a native.

Several other native vegetable juices yield permanent substantive blacks, such as the American *Rhus Toxicodendron* or *Poison Ash*, and other tropical plants, but none of these are used in Europe.

The black commonly given to all kinds of stuff is that which is produced by some vegetable astringent, particularly galls, with the salts of iron, but many circumstances must be observed in order to produce a full and good colour. Wool takes this kind of black with much more ease than linen or cotton, and is dyed in the following manner.

The woollen cloth is first dyed of a very deep blue with indigo, to give a fuller body of colour. The black is then given by astringents and iron, of which the following is Hellot's elaborate and excellent process.

For every 50 lb. of cloth take 8 lb. of logwood and as much galls, both bruised or powdered, tie them loosely in a bag and boil in a moderate sized copper for about twelve hours with sufficient water. Put one-third of this decoction with a pound of verdigris into another copper, and soak the cloth in it for two hours, keeping the liquor scalding hot but not boiling. Take out the cloth, add to the same copper another third of the first decoction, with 4 lb. of vitriol or sulphat of iron, and bring again to a scalding heat, and soak the cloth in it for an hour, stirring it well all the time. Then take out the cloth and add the remaining third of the decoction with 8 or 10 lb. of sumach, boil the whole,

lower the heat with a little cold water, add a pound more of vitriol, and return the cloth for an hour longer. The cloth is then washed and aired again, and returned to the bath for an hour, after which it is well washed in running water and fulled. It is lastly passed through a yellow bath of weld for a short time, to give a higher gloss and softness to the black. It is then washed and dried in the usual manner.

The common blacks however are given in a much simpler manner, the stuff (previously dyed blue) being first soaked in a bath of galls and boiled for two hours, and then passed through another bath of logwood and vitriol at a scalding heat for as much longer, after which it is washed and fulled.

Several observations are to be made on this process.

The previous dyeing blue is not in the least necessary to enable the cloth to take the black afterwards, but it is found to be of great service in giving body to the colour, and is never omitted in the finest blacks. The indigo blue is the best preparation for black, being a deep heavy dye and assimilates well with perfect black. When this proves too expensive for the stuff, it is sometimes prepared of a buff or fawn colour with walnut husks instead of blue.

Black is never given by a single operation: that is, the stuff is first impregnated with the galls or other astringents either at once or else by several processes, and afterwards passed into the vitriol bath. The colour is thus rendered much faster than if the whole ingredients were first mixed. A certain proportion must be observed between the astringent vegetables (of which kind are the galls, logwood and sumach) and the salt of iron, for if the former are in too great a quantity, the black is again degraded towards a grey rusty hue. Too long a maceration of the cloth has the same effect, as Lewis has well observed,^d and Berthollet remarks that a rusty colour is given to the finest black by being passed through a fresh bath of galls. The black colour is not entirely brought out till after the cloth is exposed to the air, an effect similar to the well-known deepening of the colour of pale ink some hours after it is used.

Logwood does more than merely add to the quantity of vegetable astringent, for it contributes much to the depth of colour and counteracts the brownish rust tinge which galls and iron alone are apt to give. Where the cloth is not previously blued, logwood is particularly necessary. A very fine black is produced on

blue cloth, according to Lewis, by 5 lb. of vitriol, 5 lb. of galls, and 30 lb. of logwood.

The verdigris also has a good effect in improving the colour, but it is not exactly known how it acts.

In Hellot's process the cloth already black is finished by a yellow weld bath. Madder has also been much used in the same way, and is supposed to give a velvety softness to the colour. The use of any of these finishing tints is however much disputed, and is in a good measure discontinued.

Wool is dyed black nearly in the same way as woollen cloth. The natural grease of the wool is first removed by boiling in a bath of stale urine and water, after which the wool is dyed blue and black nearly in the way above-mentioned.

Some variety of the above processes is required to give a black dye to silk. Raw silk in the state in which it is spun from the cocoons, is covered with a natural kind of gum or varnish, which gives it its beautiful orange yellow colour, and also a degree of stiffness and elasticity which is detrimental to the manufacture and must be first removed. This is done by boiling it in water for four or five hours with a fifth of its weight of fine white soap which dissolves this gummy matter. The silk loses about a fourth of its weight in this process. To dye it black it is then boiled three or four hours with about three-quarters of its weight of galls, and suffered to remain without boiling for about a day, more or less according to the kind of manufacture for which it is intended. It is then blackened in a bath of sulphat of iron, iron filings, and cherry-tree gum, with many manipulations too numerous to be here described. Silk is seldom if ever previously blued, as wool is, but sometimes a root or fawn-coloured ground is given by walnut husks. Silk requires many more dippings and alternate soakings with galls and iron than wool does, to produce a full good colour, and the quantity of galls required differs most remarkably, five or six pounds being sufficient for a hundred pounds of wool, but upwards of fifty for the same weight of silk. Hence the dyeing of silk is much more expensive.

Hats are dyed with only a single bath of the mixed ingredients. The bath is made of 100 lb. of logwood,^e 12 lb. of gum, and 6 lb. of galls boiled for some hours with water, after which 6 lb. of verdigris and 10 lb. of sulphat of iron are added, and the liquor kept just of a scalding

^d Commerce of the Arts.

^e Lewis.

heat. Ten or twelve dozen of hats are immersed by a proper contrivance into the liquid for about an hour and a half, then taken out and aired, and another set immediately immersed for the like time. Each set is dipped and aired alternately for eight times, the bath being occasionally refreshed by more of the ingredients. The verdigris is found by experience to be essential to the beauty of the dye.

It is a much more difficult operation to fix a permanent black on linen and cotton, which will stand washing with soap and long exposure to the air. The processes that succeed on wool do not answer well here, the black being very liable to degenerate to a rusty brown.

Linen or linen thread is generally first blued with indigo and then receives a mordant of alum, after which it is passed through a bath of galls or logwood, or alder, and blackened with the iron solution, for which a variety of processes are given.

A fine durable black on cotton is of still more consequence in the present immense trade of printed cottons than on linen, and much pains has been taken to equal the excellent fast black given to cotton goods in the East Indies, the process for which is not known, unless it be with the anacardium or other native vegetable juices. For many years a kind of acetite of iron has been used very largely in England as a substitute for the sulphat in the black dye, and also partly as a substantive colour, by which alone many useful shades of buff, nankeen, and other dyes are given. This acetite is made by macerating refuse pieces of iron in sour beer, vinegar, elder-berries, and other substances that afford the vegetable acids and produce in time a very strong uncrystallizable high-coloured solution. Of late years too the pyroligneous acid (obtained from the distillation of wood in making the best charcoal for gunpowder) and the empyreumatic acid of tar have been used very extensively in calico-printing for similar purposes and with very compleat success, but the precise mode of application is kept secret. It appears that galls or similar vegetable matter are not required with this preparation, but the place is supplied with madder, which with a deep iron ground may be made to give a very dark purple-brown hardly distinguishable from black.

Since cotton and linen, which are of vegetable origin, have naturally less affinity with colouring matter than wool and animal matters, dyers have been in the habit in many parts of

the world of impregnating linen and especially cotton with many compound mordants, the united effect of which is certainly in many instances to enable them to take and retain colours with much more perfection than any simpler process could obtain. Sometimes these mordants are animal glues, animal oils, dung, &c. and it has been very happily conjectured that the great advantage of these is in some degree to *animalize* the vegetable fibre, as it were, and thus in point of affinity with colouring matter to bring it more on a level with wool, silk, and the natural animal fibres. The fine turkey red of madder fixed on cotton by a very complicated process, is a striking instance of the use of these compound mordants, as will be afterwards mentioned. The following process for dyeing linen and cotton of a fine durable black is given by Mr. Vogler, an eminent practical artist, in which animal glue is used as a mordant, together with a solution of lead, which last seems to have a strong affinity for the materials of which the black dye is composed.

Mix in a large bottle a quart of soft water with 2 or 2½ ounces of common aquafortis, and throw in from 2 to 3 ounces of litharge. Set the bottle in a warm place frequently shaking it, till a solution is made, which when used should be poured off clear from the sediment. In this dilute nitrated lead first soak the linen or cotton thread (without heat) for ten or twelve hours, then take it out, wash it and wring it well. Next dip the thread into a moderately strong warm glue water, wring it out but do not wash it, and let it dry in the shade. Next make a decoction of ¼ of an ounce of galls in a quart of water, and when they have boiled for ten minutes throw in ¼ of an ounce of salt. Then soak the thread therein for seven or eight minutes with a boiling heat, wash, wring and dry as before. The thread has now a dark yellowish grey colour. Afterwards dissolve ¾ of an ounce of sulphat of iron with as much salt in a quart of clean hot water, soak the thread therein for eight or ten hours, after which wash and dry. The colour is now black but is much improved by the following operations. Boil ¾ of an ounce of logwood in a quart of water for ten minutes, after which add a quarter of an ounce of starch, and when well mixed put in the blackened thread or stuff, and boil for 7 or 8 minutes, after which wash it in cold water and dry. Lastly, the colour, which is much improved by the foregoing operation is fixed by the following. Make a bath of one

ounce of bruised galls and a quart of pretty strong glue, and when it has boiled for 10 minutes add one ounce of vitriol of iron, and allow the whole to cool with frequent stirring. Then soak the thread for an hour in the liquor, after which wring it out and dry it in the shade. The dye is then complete. Though the above process includes many operations it does not appear needlessly complex, but on the contrary is very judicious, and agreeable to the long established practice of the art. Cloth of cotton or linen may be dyed in this way, according to the author, as well as thread.

Of Grey.

Many of the varieties of grey, iron-grey, slate colour, &c. are given by processes in general similar to those for black, but with smaller quantities of the ingredients, and especially a shorter time of immersion. They are often finished with a weak bath of weld, cochineal, Brazil wood, and other livelier colours to give some particular tints.

Of Blue.

The principal material for this most important colour is indigo, a singular vegetable preparation produced by the fermentation of the leaves of a small plant, the *Indigofera Tinctoria*, and one or two varieties of the same genus, cultivated abundantly in many tropical countries, particularly in Mexico and other parts of Spanish America, and of late years very largely in the British East Indies.

Many important chemical facts are connected with the preparation of this colouring matter, which, with the analysis and fuller account of the methods of solution for the purpose of dyeing will be referred to the article *Indigo*. It will be sufficient to observe in this place that indigo is brought over in the form of cubical cakes or lumps, which (when the article is of the best kind) are of a very deep blue colour almost black in mass, very light, breaking short and easily reduced to powder; when rubbed with the nail shewing a polished copper-coloured streak, and of a peculiar smell, which particularly shews itself when in solution.

Indigo is soluble of itself in scarcely any known menstruum except the stronger acids; water, alkalies, spirit of wine, &c. added singly having no action on it whatever. The reason of this great insolubility appears from multiplied experiments to consist in the high degree of oxygenation in which blue indigo in its common state exists. That the blue colour depends on the action of the air is obvious from the

circumstance, that in the preparation of this dye the colour of the fermented plant is at first green, but by exposure to air it takes the deep and permanent blue, for which it is much valued. Other experiments which will be mentioned under this article make it appear that the change from green to blue is owing to this cause.

In order to render indigo soluble for the purposes of dyeing a fast colour, a complicated process is requisite. First, some substance must be added which is capable of partially deoxygenating indigo, or of reducing it to a state somewhat similar to the recent green pulp of the indigo while under manufacture; and next, a liquid must be added capable of dissolving the deoxygenated indigo, that it may be applied to the fibres of the stuff immersed in it. The former object is fulfilled by a great variety of substances, so different in nature, that it is hardly to be conceived that they can have any other property in common than that to which their utility is attributed, namely, that of depriving indigo of its oxygen.

The additions actually employed for this purpose, or found by experiment to be capable of being so used, are other dyeing matters, such as madder or weld, vegetable mucilaginous substances, such as sugar or gum,* and also many metallic *sub-oxys*, or metals only partially combined with oxygen and capable of absorbing from the indigo that additional quantity of this principle which is requisite to complete saturation. The sub-oxyd of iron is chiefly used for this purpose, and is made extemporaneously by mixing lime and sulphat of iron; and as a proof of the necessity of using *sub-oxyd*, and not a perfect oxyd, it may be added that the red perfect oxyd of the same metal has no effect whatever in bringing indigo to a soluble state. Dr. Bancroft also has found the sub-oxyd of tin equally beneficial. The sulphuret of arsenic or orpiment is also commonly used for the same purpose.

The indigo thus deoxygenated is now soluble in the alkalies or in lime-water, which are the solvents actually employed in the composition of the indigo vat.

Indigo is a *substantive* colour, or one that requires no mordant to be previously united with the stuff to be dyed. It is also one of the fastest colours known, but to render it permanent, it must be presented to the fibres of the cloth in its green deoxygenated state. Hence it is that cloth when it comes out of the indigo vat is

* Bancroft.

always of a deep green, but by exposure to air it soon changes to a fine deep blue. This change of colour of the solution of indigo from green (or, if much alkali has been used, yellowish green) to blue, forms a very entertaining experiment in the small way. The same change is constantly going on upon the surfaces of indigo vats, which, being in contact with air, are always covered with a fine variegated green and copper-coloured scum that is perpetually passing to blue, unless stirred in and mixed with the mass below.

This constant change in the nature of the indigo demands an equally constant attention to the state of the vat on the part of the workman, to keep the liquor at the proper point of oxygenation; for when the blue colour is regenerated, the indigo again partly separates from the lime or alkaline solvent, or remains only suspended in it as a fine impalpable powder which will not adhere to cloth with any permanence. A fresh addition of the deoxygenating materials also becomes from time to time necessary; but again, too great a quantity of this and of the lime or alkali is equally detrimental, and so far alters the nature of the indigo that it will no longer change to blue by air, but remains of a rusty yellowish green.

Woad, which is a fecula or dried pulp made of the fermented leaves and stem of the *Isatis Tinctoria*, and in nature not unlike indigo, is commonly used along with indigo in the dyeing of woollen. Woad is never employed alone, for the blue colour which it gives, though full-bodied and very permanent, is not sufficiently bright and glossy. In its nature and affinities for oxygen it appears considerably to resemble indigo.

The bath in which wool is dyed blue is not a copper boiler as is the case with other dyes, but is a large wooden vat generally sunk in the ground fitted with a cover to protect it from the draught of external air, and to preserve the temperature more uniform. The colour is sometimes procured from indigo alone, sometimes from a mixture of indigo and woad. The latter is prepared in the following way.^h

Two hundred parts of woad broken small are first thrown into the vat, to which is then added a hot decoction of 15 parts of weld, as much madder, and a basket of bran all boiled in a separate vessel with water enough to fill the wooden vat. This is allowed to remain at rest for six hours, when the whole is well stirred together and again let to rest. A kind of fer-

mentation is thus produced in the vat, attended with very strong acrid vapours, owing to the beginning decomposition of the woad. After a sufficient time (during which the stirring is often repeated) 4 parts of lime are added which turns the vat of a black colour, and makes the fumes still more acrid. Immediately afterwards from 5 to 15 parts of indigo (more or less according to the depth of colour to be dyed) mixed up with water into a cream-like fluid are poured in, and the whole stirred and covered. The disoxygenation of the indigo is effected by the action of all the vegetable matter already in the vat, and when thus altered it is dissolved by the lime. The signs of the solution of the indigo are the rising of a blue copper-coloured and variegated scum, and the liquor beneath becoming of a bright green.

Before the cloth is put into the vat, it is wetted with clear hot water and wrung out. The time of remaining in the vat depends on the depth of colour wanted and on other circumstances.

It comes out green, as already mentioned, but the colour changes to blue by exposure to air. It is then thoroughly washed to discharge all the colouring matter that is not fixed, and dried in the field.

Dr. Bancroft thinks (and with some reason) that the weld and madder added to this vat have little other effect than to supply vegetable matter for the fermentation which is to disoxygenate the indigo, and hence that instead of these expensive ingredients, any herbs, or a greater quantity of bran, or coarse sugar, or many other cheaper materials might be substituted.

A richer blue bath, that gives a finer and softer colour (but is more expensive on account of indigo alone supplying the blue colour) is made by boiling in a copper with sufficient water, 9 parts of pearl ash, with as much bran and 1 part of madder, after which 9 parts of indigo ground up with a little water are added, and a gentle heat kept up for about forty-eight hours, stirring the whole well together three or four times during the solution. In this case the alkali is the solvent of the indigo when deoxygenated by the bran and the madder.

In other indigo baths the ammonia contained in stale urine is the solvent of the colouring matter, and the deoxygenating matters are madder and tartar. The variety is endless of combinations thus afforded by the use of a vast

number of vegetable matters, with lime or any of the alkalies.

Silk is dyed in a similar indigo vat with the foregoing, and without woad. For the very deep colours however it is found necessary to prepare the silk with a high purple from archil.

Metallic sub-oxyds and sulphurets were mentioned to be equally powerful in deoxygenating indigo, with vegetable matters, and to be employed accordingly. This chiefly takes place in preparing the indigo vats for cotton and linen. A very simple and efficacious mode of composing this kind of blue vat is to mix together one part of indigo, 2 parts of sulphat of iron, and 2 of lime with sufficient water in a vat, to stir them together very well for a considerable time, and then suffer them to remain two days at rest. In this case part of the lime first decomposes the sulphat of iron, separating the sub-oxyd of iron, which then acts on the indigo and brings it to the state of the green-yellow or deoxygenated indigo, at which time it becomes soluble in the remainder of the lime. This vat therefore consists of a solution of deoxygenated indigo by lime, mixed with some sulphat of lime (arising from the decomposition above mentioned) and at the bottom is a sediment of the oxyd of iron, with any undissolved lime or regenerated blue indigo that may be contained. The cotton comes out of the vat green as in the former case, and turns blue by exposure to air. It is the constant practice after the cotton is dyed to pass it through a cistern containing cold water with a small proportion of sulphuric acid. This is found to heighten the colour, and is of further use in dissolving out any adhering lime or sulphat of lime which would give a harshness to the stuff and impair the lustre.

Alkalies are also frequently used instead of lime in the above vat. Their effect is precisely the same as that of the lime, only being themselves much more soluble in water than lime, they will bear a much larger proportion of indigo, and of course will form a much deeper and richer dye.

The indigo rapidly *regenerates* or recovers its oxygen (and with it its blue colour) at the surface of all these solutions, and in so doing it separates from the alkali or lime-water which held it dissolved, and partly sinks to the bottom, partly remains entangled in the scum. Hence the use of the occasional stirrings to mix the regenerated indigo with the other materials, and again dissolve it. Frequent additions are also

used of the deoxygenating and dissolving substances to refresh the vat when long exposed to air, and bring it back to the proper state for dyeing.

It is remarkable that the salts of copper are found by constant experience to have a totally opposite effect on indigo from the salts of iron, the former being observed not only to have no effect in rendering indigo soluble, but even to prevent the operation of the sub-oxyds of iron, and to hasten the regeneration of dissolved indigo. This is supposed to be the reason why cottons, first soaked in sulphat of copper, and then passed through a very weak indigo vat, extract at once all the colour, the copper determining the immediate separation of the indigo.

Orpiment or sulphuret of arsenic is chiefly used in preparing the indigo solution for topical application in calico-printing. Mr. Hauffman mixes for this purpose 25 gallons of water with 10 pounds of indigo (more or less according to its quality), to which is added 30 lb. of good pearl ash, 12 lb. of lime, and 12 lb. of orpiment. The whole is boiled for a sufficient time with stirring, and forms a very strong yellow liquid solution, which turns blue by exposure to air. For calico-printing it is thickened either with gum senegal or with starch to the consistence of a jelly, and when strongly impressed on cotton it forms durable blue figures. The extreme inconvenience of this and all other solutions of indigo in lime or alkalies, is the impossibility of preventing the perpetual regeneration of the indigo before the whole is used; and as all the colour prematurely regenerated is readily washed away in the after processes, it becomes extremely difficult to maintain an uniform shade of blue through the pattern of a whole piece of cloth. The gum or paste are of further use in retarding this premature change of the indigo.

According to Professor Pallas^k, cotton and silk are dyed blue at Astracan, by a bath very similar to the simplest indigo vat for wool, the deoxygenating substance being honey and the solvent of the indigo being soda.

The proportions are 2 lb. of indigo, 5 lb. of carbonat of soda, 2 lb. of lime, and 1 lb. of clarified honey. These are put with sufficient water into large earthen jars set in brick work over a fire, which will bear a boiling heat, and are heated with frequent stirring, till the indigo is dissolved.

Saxon Blue is the name given to a totally different preparation of indigo from those hitherto

^k Ph. Mag. vol. I.

mentioned, and is made by digesting this colouring matter for above twenty-four hours, with a gentle heat, in about four times its weight of strong sulphuric acid. This acid (which thus concentrated, and with the assistance of heat, would char and destroy most vegetable matters) produces but little apparent alteration on indigo, but dissolves it into a fluid of an inky blackness when undiluted, but when largely mixed with water, it produces a very beautiful transparent blue liquor, of a brighter colour than the alkaline solutions of indigo, and capable of giving very fine dyes to cloth, silk, or cotton. The great inconvenience however of the Saxon blue is the extreme difficulty of rendering it a tolerably fast colour, for when applied in the common way it is soon destroyed by washing, especially with soap, so that the indigo in the state in which it exists in this solution appears to have but a very feeble affinity with animal or vegetable fibre, a remarkable contrast to the habitude of the same colouring matter when deoxygenated and dissolved in alkalies.

The colour of the Saxon blue undergoes no notable change like that of the common indigo vats, the stuffs dyed in it coming out blue and not green. The colour takes upon woollen cloth with great rapidity, so that it is very difficult to dye it uniform through a whole piece. Some scientific dyers have thought that this dye was more permanent when the solution was saturated with an alkali just short of the point at which the indigo begins to separate, for an entire saturation of the acid will precipitate the indigo nearly unchanged. Other artists have thought alum of use in this case in fixing the colour. The action of acids upon indigo will be further mentioned under the article *Indigo*.

Prussian Blue is so beautiful a colouring matter for painting, that many attempts have been made to fix it permanently on cloth of different kinds. Prussian blue, or prussiat of iron, is naturally a fast colour, resisting the action of light and air for any length of time, but when dissolved in any of the alkalies, or in lime-water, the blue is immediately destroyed, and a pale straw colour substituted. The solution is a triple compound of prussic acid, iron, and the alkali or lime used. If any acid be added to the above prussiat to the full saturation of the alkali or lime, the blue colour is restored without immediately precipitating the prussian blue.

Two methods have been adopted of preparing this colour for dyeing, the one, by mixing it with muriatic acid, in which case it is only suspended and not dissolved; the other, by dissol-

ving it in alkalies or lime, and saturating the solution to that point at which the blue colour is restored. The prussian blue in either case has sufficient affinity with the fibre of cloth to unite with it rapidly and firmly.

Some have used an acetite of iron as a kind of mordant to the cloth before the application of the prussiated alkaline solution. It is necessary in all cases where this solution is used, that it be neutralized with an acid to diminish the strong affinity between the alkali and colouring matter, which without this assistance the cloth alone could not overcome.

Two capital inconveniences have hitherto been found to attend the use of this substance as a blue dye, the one the extreme difficulty of making it take at all uniformly on a moderate extent of cloth; for an immersion of a very few minutes is found sufficient to give the full effect of this colour, and hence the dye is deposited so rapidly as to be constantly wavy and uneven. The other defect is that it is readily discharged by soap, the alkali in the soap having the same effect on the colour fixed in the fibres of cloth as it has on prussian blue in substance, so that after a very few washings the colour becomes of a dirty yellowish brown. Stuffs dyed with this colour therefore must be washed with bran, or oatmeal, or in any other way in which no alkaline substance is employed.

A basis of other colours is often used in dyeing with prussian blue.

Very beautiful greens are produced with this colour, and the permanent yellows.

Dr. Bancroft, in his curious experiments on this colouring matter, observes, that when cotton is printed with a mixture of adjective colours, and an iron mordant *without alum*, and afterwards dyed with prussian-blue solution, the result is not a mixture of the blue with the adjective colour already applied (for example, green, where the latter is a yellow) but is simply that colour which the prussian solution would produce with the iron mordants without the adjective dye: or in other words the prussian blue appears merely to displace the first applied colour, and unite with the iron mordant. It has however the capital advantage of dyeing much more uniformly than in the common way, so that in this instance the adjective colour appears to divide and distribute the mordant more accurately than could be done without it. On the other hand, where the adjective colour is fixed with an alum mordant, the prussian blue cannot displace it, and therefore unites with it, forming an intermediate shade of colour.

Of Yellow.

Yellow is so common a colour for the extractive part of vegetables as to furnish a considerable number of dyes, many of which are only used extemporaneously by uncivilized nations in different parts of the world, and scarcely known beyond those parts. The yellow dyes actually employed in this country are few, and it happens unfortunately that the most beautiful are not the most permanent. All the known yellows are adjective colours, or such as require a mordant, and on the whole this is a dye easily given, but always (when on cotton and linen), liable to be impaired by the action of light and air.

Weld (*Reseda Luteola* Linn.) is a slender plant growing to the height of about three feet, and cultivated for dyeing in this country, as in many other parts of Europe. The plant is cut when ripe, and simply spread out to dry, after which it is tied up in bundles, and used in this state without any other preparation. It requires nearly a boiling heat to enable water to extract the colour of weld with effect, and a decoction of three quarters of an hour before the whole of the colour is exhausted, during which time it is loosely tied in a bag, and kept down in the boiler by a heavy wooden frame. The decoction of weld, when concentrated, is a brownish yellow, when dilute it is more of a lemon yellow with a shade of green. Alkalies deepen the tint towards an orange or brown, but acids make it lighter. Alum gives a yellow precipitate in the decoction of weld, and the clear liquor remains of a beautiful lemon colour. Tartar is considered as brightening the colour of weld, and the solutions of tin produce this effect in a great degree, giving it at the same time a yellowish green tint of great delicacy.

Weld is considered by most dyers as, on the whole, the yellow which unites beauty with durability in the highest degree.

Wool and woollen cloth is dyed with weld (according to Hellot) in the following way. The wool is first cleansed in the usual manner, and then passed through a bath of about 4 parts alum and 1 of tartar to every 16 parts of wool. The quantity of tartar is determined by the greater or less brightness of colour wanted to be given. It is then dyed in the weld bath, for which about 3 or 4 parts of weld (often much less) are used to 1 part of wool. For economy, the weaker shades of colour are dyed in the same bath after the stronger are finished.

A golden yellow with more or less orange is given by a weak madder bath after the welding.

Silk is dyed of a golden yellow generally with weld alone. The stuff is first boiled in soap water, alumed and washed, then passed twice through a weld bath in which, the second time, some alkali is dissolved which gives a rich golden hue to the natural yellow of the weld. A little annotta still further deepens the colour. The solutions of tin also apply very well to silk, and with weld give a bright clear yellow.

To dye cotton yellow¹ it is first cleansed with wood ashes and water, rinsed, alumed, dried without further rinsing, and then passed through a yellow bath in which the weld is somewhat more than the weight of the cotton. When the colour has sufficiently taken, the cotton is thrown into a bath of sulphat of copper and water and kept there for an hour, after which it is boiled with white soap-water, and finally washed and dried.

If a deeper jonquil-yellow is wanted, the aluming is omitted, and instead, a little verdigris is added to the weld bath, and the cotton finished with soda.

It is particularly in giving the lively green lemon yellow that weld is preferred to all other materials. It is however expensive, considering the small proportion of colouring matter to the weight of the plant, and the dye is not extracted readily with less than a boiling heat, which in callico-printing is sometimes a great inconvenience. It is also found to degrade and interfere with madder colours more than other yellows, which is another disadvantage in printing, where patterns are first impressed with madder-colours, and the whole finished with a weld bath.

Quercitron Bark. The bark of the American oak (the *Quercus Nigra*, Linn.) long used as a yellow dye in the countries where it is indigenous, was first introduced into this country by Dr. Bancroft, from whose full and elaborate account of its properties the following general facts are extracted.

The colouring matter of this bark may be readily extracted by water only blood-warm. The infusion in hot water is rather turbid, and there separates by filtration a small quantity of yellow resin. The infusion will yield by evaporation an extract which contains the colour in a very concentrated state, but when kept for a short time does not answer for dyeing so well as the unprepared bark. The decoction of

¹ Berthollet.

quercitron is of a yellowish brown, darkened by alkalies, and rendered lighter by acids: alum causes a very small precipitate of a deep yellow: the solutions of tin produce a very lively yellow and a copious sediment.

The quantity of colour contained in quercitron bark is very great compared to its weight, much more than in an equal weight of weld, to which it approaches the nearest in beauty and durability combined.

Wool may be dyed of a fast yellow with quercitron by being first cleaned in the usual manner, boiled for about an hour with one-sixth of its weight of alum, in sufficient water, then without rinsing transferred into a copper containing a decoction of as much quercitron bark as there was used of alum, and turned through the boiling liquor over the winch as usual, till the colour appears to have taken sufficiently.

After this, some chalk in the proportion of about one pound for every 100 lb. of the cloth is to be mixed with the dyeing liquor, and the operation continued ten minutes longer, when the process will be finished.

It may be observed that chalk or alkali is of great service in all yellow-dyeing, whether with weld, quercitron, or any other colour, when the mordant is alum, as this addition helps to bring out and heighten the dye.

The yellow of quercitron given in this way is however inferior to that of weld.

The salts of tin, being powerful mordants for almost every colouring matter, may be employed with advantage in dyeing yellow, particularly the finest colours. Dr. Bancroft recommends the murio-sulphat of tin (made by dissolving 14 ounces of tin in a mixture of two pounds of strong sulphuric acid, and three pounds of the muriatic) of which 10 lb. with as much quercitron bark, are sufficient to give the highest orange yellow to 100 lb. of cloth. The bark is first put into the boiler (tied up in a bag) and boiled with water for a few minutes, after which the tin solution is added, the mixture well stirred, and the cloth, previously scoured and wetted, is then passed briskly through the liquor over a winch for a sufficient time, which is generally no more than a quarter of an hour.

With an addition of alum a pure golden yellow with less of the orange is produced; for the delicate green yellows Dr. B. uses the tin solution with both tartar and alum.

The method of dyeing cotton yellow with weld has been already mentioned. A similar

way will answer with all the yellow dyes, but owing to the small affinity which the fibres of cotton have for colouring matter, it is extremely difficult by any means to fix a full, equal and lasting yellow on this material. Even the salts of tin which are so useful as mordants to wool or silk, Dr. Bancroft observes to have no good effect with cotton, and to be worse in every respect than alum.

On account of the superior beauty and durability of the yellows given to cotton in the process of calico-printing to those of common dyeing, Dr. Bancroft proposes the use of the printers mordant, the acetite of alumine, in general dyeing. When used for this purpose it is not to be thickened with gum or starch, but prepared simply by mixing one part of sugar of lead with three of alum and sufficient water. The cotton (and the same applies to linen) should be first soaked for two hours in the aluminous liquor kept blood-warm and then dried in a stove: then soaked a second time in the mordant, dried without rinsing in water, then soaked in lime-water, which tends to fix the alumine in the cloth and neutralizes the acetous acid. After this (or where a very durable yellow is wanted, with a third aluming and liming) it is fit for the yellow bath, in which 12 or 18 pounds are sufficient for 100 of the linen or cotton. A finish with a very weak solution of sulphat of copper seems to raise the colour.

Some of the further uses proposed to be made of the quercitron by Dr. Bancroft, will be mentioned when describing the cochineal scarlet and calico-printing.

Old Fustic, so called in this country, (the *Bois Jaune* of the French,) is the wood of a large tree, the *Morus tinctoria*, which grows abundantly in many parts of the West Indies and the American continent.

Fustic is of a sulphur colour, abounding in colouring matter, which is much more durable than any of the other yellow dyes, inasmuch as when applied even substantively, or without a mordant, the dye is considerably durable, but still more so when used with the same mordants as weld or quercitron.

The decoction of fustic in water, when strong, has a deep and somewhat dull red yellow, and by dilution becomes orange yellow. Acids produce in it only a slight precipitate, which alkalies redissolve, rendering the liquor red.

Fustic though valuable for the durability of its colour is seldom used for the pure yellows, as the colour which it gives is dull and muddy. It is chiefly used in compound colours, as in

forming green with a Saxon-blue basis; or in producing with a mixed mordant of alum and iron liquor an infinite variety of drab and olive dyes, where the natural dullness of its colour is of no consequence. It is used chiefly in general dyeing and seldom in printing. It goes much further than weld.

Young Fustic, the *Fustet* of the French dyers, *Rhus Cotinus* or *Venice Sumach*, is a shrub growing in Italy and the South of France, which gives a fine greenish yellow but without any permanence, so that it is never used alone, but only as an accessory colour to heighten cochineal and other dyes and give them an approach to yellow.

The common *Sumach* of Spain, Portugal, and other parts of Europe, gives a yellow dye with the aluminous mordant, but very pale and dull. It is therefore never employed for this purpose, but on account of the large quantity of gallic acid it contains, it is of great service in black dyes and all the degradations of this dye.

Saw-Wort (*Sarrette*, Fr.) the *Serratula Tinctoria* of Linnæus, is a useful plant which gives a good lemon yellow to wool when used with the aluminous mordant.

Dyer's Broom (*Genestrole*, Fr.) the *Genista Tinctoria* of Linnæus, a plant abundant in dry hilly countries, gives a tolerable yellow, which with an alum and tartar mordant is sometimes used in the inferior woollen goods.

Avignon or *French berry* (*Graine d'Avignon*) is a very beautiful but remarkably fugitive yellow, which can never be used with advantage to the consumer except where a very temporary but fine colour is wanted.

The American Golden Rod (*Solidago Canadensis*) though not commonly introduced, appears by the experiments of able dyers to be one of the very best of the vegetable yellows, little if at all inferior to weld.

Several other vegetables have also been occasionally used for yellow dyes, but are of little importance. In fact scarcely any other substance is actually employed for this colour than weld, fustic, and quercitron.

Of Madder Reds.

The root of madder (*Rubia Tinctorum*) is one of the most important of the colouring matters, on account of the great body and quantity of colour which it possesses, its durability when fixed by proper mordants, and the immense variety of shades of colour which are obtained from it by various admixtures.

Some facts concerning the cultivation and analysis of madder will be described under that

article, the general result of the analysis is that madder naturally contains two distinct colouring matters, one of which is of a deep blood-red (for which alone it is valued) and the other of a dun or yellow brown, more soluble than the former, but so intimately combined with it as materially to deteriorate the natural beauty of the red portion.

The natural colour of madder therefore is a dull orange red, with much body but little brightness; but by various means (some of them extremely complicated) the art of man has been enabled to extract and fix dyes of great beauty from this ingredient.

Madder is an adjective colour, its stains being removed from all kinds of cloth without much difficulty by washing and exposure, unless fixed by mordants. Of these the aluminous salts are the most powerful, and most commonly employed. The salts of tin are not used in fixing the colour, but when fixed, they render it more lively.

Wool or woollen cloth when to be dyed with madder, is first soaked in a bath of alum and tartar in varying proportions, but when the latter is in excess the colour, though solid, degenerates to a cinnamon brown. The madder added to the bath of alum and tartar must scarcely be heated more than blood-warm, otherwise the dye will become browner and deeper. At any time however the madder reds on wool are not so beautiful as those on linen or cotton, though easier given, and with more body.

The fixing a permanent, full, and beautiful madder red upon cotton, and especially linen, is perhaps the most difficult and complicated process in dyeing, and one on which more has been written, and more experiments and enquiries have been made than perhaps any other part of this chemical manufacture. The affinity of cotton, (and the same applies to linen) to madder-colour is so small, that even the aluminous mordant will not alone be sufficient to enable it to resist frequent washing, and especially the bleaching effect of the sun's rays. Hence it is found necessary previously to fix into the fibres of the cotton one or more substances capable of uniting with both the mordant and the colouring matter, and to retain them with great force.

There are two principal kinds of madder colours known, but with a great variety of intermediate shades; one is the common red, not very brilliant, but considerably permanent, in which the substances used are chiefly, first, any vegetable substance containing a

large quantity of tan, and above all, galls, secondly, an aluminous mordant added to the galled cotton, generally with a certain portion of tartar; thirdly, the madder colouring matter, and fourthly, a finish with an alkaline bath, which indeed is not essential to the fixity of the colour, but is found most materially to heighten and improve it, chiefly as has been supposed by removing the brown-yellow part of the madder which always mixes more or less with the red, and degrades it. The other madder colour is a very bright, beautiful, and most durable red, which, from having long been, and being still prepared at Adrianople, and other parts of the Levant, with a perfection scarcely imitable, is called the *Adrianople or Turkey Red*, and if the accounts of its preparation are accurate, it is the most complicated and tedious process in the whole art of dyeing.

The true Adrianople red, besides its uncommon beauty, has the property of resisting more than any other madder red, the action of soap, alkalies, alum, acids, and all other reagents. On this account nitric acid is employed as a test to distinguish this red from any spurious imitations. If the latter is immersed in aqua-fortis, or common nitric acid, it soon loses colour, and in about a quarter of an hour it is quite white, whereas the genuine Turkey red cotton will remain nearly an hour without any perceptible loss of colour, and retains an orange tint to the last.

There can be no doubt too that much of the beauty of the Levantine red is owing to the superior quality of the madder, as will be noticed under that article, so that even with the best madder of the North of Europe, it is probable that no accuracy in the dyeing can entirely make up for this radical difference.

We shall not detail the *seventeen* distinct operations (given by the Abbé Mazeas) as employed in this process, but only describe the general way of proceeding.

The cotton yarn is first thoroughly cleansed by long boiling in water. The next step is to impregnate it with an *animal* substance, which, having a much stronger affinity for colouring matter than the cotton itself, forms an excellent basis or substratum on which the dye may fix itself by the subsequent operations. The animal matter in this instance is sheep's dung. Oil is another intermede also used, and the effect of this is certainly to assist in fixing the colour, and rendering it afterwards insoluble in all other substances. The oil and the dung are blended, and both together dissolved in a ley of soda, and the cotton well mixed with it with much manual exertion.

The cotton is then steeped in olive oil, without the dung, brought to the state of a milky liquid, or an extemporaneous soap, by just sufficient soda. It is then steeped in three successive baths of soda and water, each stronger than the last, in order thoroughly to separate all the oil that loosely adheres to the cotton, or all but what is intimately combined with it. This is necessary to make it take up the soluble part of the galls with which it is combined in the next operation. A strong decoction of galls is then made, and the cotton is long and thoroughly steeped in it, with much wringing and pressing, after which it is stretched and dried as quickly as possible.

The cotton now may be considered as a compound of vegetable fibre with the animal matter of dung, with oil, and with tan very intimately combined, and it is then in the state fit to receive the proper mordant for the madder colour. This mordant is Roman alum, in which the cotton is carefully steeped for a due time, and then stretched and dried.

After this long preparation the cotton undergoes an exact repetition of the whole process step by step, the dung bath only excepted; that is, of oiling, steeping in soda, galling and aluming.

The whole of this labour being performed, the cotton is thoroughly dried and aired, and is then of a dun or root colour, this hue being given by the galls. The next step is the madding, but in order more fully to animalize the cotton a small quantity of sheep's blood is mixed with the water in the boiler in which the madder is dissolved. The selection of the madder depends on the precise colour required to be given; the quantity is always twice the weight of the cotton. When this bath has got to a lukewarm heat the hanks of cotton are steeped in it well stretched on wooden frames, that keep the thread sufficiently asunder to allow the dye to penetrate thoroughly and uniformly.

This steep lasts an hour, during which the heat of the bath is slowly increasing, and after it begins to boil, the cotton is taken off the frame and let to lie loose in the vessel for an hour longer, the liquor being all the while kept at a boiling heat. After this, the colour of the bath being exhausted, the cotton is taken out and washed in running water, stretched, and dried. Lastly the cotton, now thoroughly and durably dyed, is finished by being boiled for four or five hours in a closely covered vessel in a solution of white Marseilles soap, olive oil, and

soda. This finishing brings out the colour, and much increases its richness and durability.

Such is, according to the best authorities, the curious and complicated process for dyeing the beautiful Adrianople red. On the whole it appears that the saving which may be made in imitating this process is rather in the number and extent of the different operations, than in the actual omission of any one part. The animal matter, the oil, the soda, the galls, and the alum, appear all to have their distinct uses, and probably it would be very difficult to dispense with any of them (or substances similar to them) without injuring the perfection of the dye.

The fine imitation of this colour made at Montpellier is conducted in a manner closely following the Turkey process according to the testimony and actual experience of Chaptal.

The observations of this excellent practical chemist give many important rules with regard to the choice and use of the materials too minute to be fully detailed in this place. Instead of sheep's dung the gastric liquor contained in the stomach of ruminating animals is employed, in each case, mixed with the oil and soda into a kind of oleo-animal soap. The oil should be of that kind which remains permanently united with caustic alkali into a uniform milky soap, without subsiding or running again into drops in any sensible degree. This kind of oil is probably that which is the freest from extractive matter, and the observations of other chemists have found that linseed oil which contains very little extract is even better than any kind of olive oil.

It also seems necessary that in the mixture of oil and alkali the oil should be in excess, or in greater quantity than in the proportions which constitute common soap: for the use of the alkali is chiefly to divide the oil and enable it to penetrate uniformly into the cotton, but if there were no excess of oil it is not likely that the alkali would abandon any of it to the fibres of the cotton. Soda does not appear to be essential, potash being found to answer as well.

The galling is one of the nicest operations. The cotton should be made to take the galls very uniformly, and should be dried rapidly, as the action of the air is found so far to affect the soluble matter of the galls that, if much exposed to it, the outer part of the cotton will become dark, and the remainder grey, and the subsequent colour will in consequence take unequally. Sumach is used with the galls in rather a larger proportion. The repetition of

the oiling, galling, and aluming is practised at Montpellier as in Turkey. In the finishing part two operations are used. The first is, as in Turkey, boiling with soda and soap in a very high temperature. The boiler is closely fitted with a strong cover with only a very small hole for the exit of the vapour, and by the heat of the fire beneath the confined liquor is made to receive a heat certainly above that of common boiling, similar to what takes place in a digester. This brings out the colour to a very beautiful red, but it is further heightened by the final operation which was long kept secret, and which consists in passing the cotton through a mixed solution of nitro-muriat of tin and alum, at a blood heat.

Linen thread is dyed of a fine red by the same method, but a still greater number of successive operations are required, and in particular the alkaline leys should be much stronger.

Madder reds of extreme beauty are prepared by the Armenian dyers settled at Astracan. The process as given by Professor Pallas^m is more simple than that practised at Adrianople, but agrees with it in the essential particulars. The madder is a fine sort that grows wild in several parts of Persia, and is dried and ground for use. The oil employed is procured from the entrails and refuse parts of the sturgeon, beluga, and other fish that are so abundant in the Volga. This supplies both oily and animal matter. The alkali employed is a coarse native soda, prepared by burning various salt plants in the vicinity. But the oil seems to be used without alkali, the soda being only employed in the finishing. The general process is as follows: the cotton yarn previously washed and well dried is laid in a tub, and covered with the fish oil, where it remains for the night. In the morning it is taken out and hung up in the air on poles. This alternate steeping in oil during the night and airing during the day is continued for a week, after which the yarn is washed in the river and dried. A strong decoction is then made of pulverized sumach leaves and galls, to which, when still hot, alum is added. The galls and alum are in the proportion of 5 pound of each to every pud (40 lb.) of cotton. This compound liquor is poured on the cotton, and well worked in with the hands, and the yarn again dried. It is then fit for the madding, in which sheep's blood is here also used along with the madder. The whole operation is finished by boiling the dyed

cotton with a ley of impure soda in large clay pans with a very narrow neck, and set in brick over a fire place. The boiling continues for twenty-four hours.

A dye-house for giving to cotton yarn a fine red equal to the Turkey red was established at Glasgow by Mr. Papillon, the secret of which was purchased by the Commissioners for Manufactures in Scotland, and has been made public not long since.^a It consists of a very close imitation of the Adrianople process, as already described, but with a considerable saving in the length and number of applications. The particulars need not be here enumerated, but it may be mentioned generally that it consists of the distinct operations of boiling with soda,—steeping in a compound bath of sheep's dung, oil, soda and other ingredients—oiling without the dung—galling—aluming—dyeing with madder and blood—fixing the colour with the dung and oil steeps—and lastly brightening the dye with a finish of soap-water and soda.

Mr. Hauffman in his observations upon Adrianople processes, announces a great simplification in the number of processes and an alteration in the mordants, by which he asserts that a red may be procured fully equal to that of the Levant.^o The mordant which he proposes is a compound solution of alumine and oil in caustic alkali, and is made in the readiest way by adding caustic alkali to a hot concentrated solution of alum, which first precipitates, then redissolves the alumine, after which a small portion of linseed oil (and probably fish oil would answer full as well if not better) is to be put in, and the whole mixed into a cream-like liquor. Cotton steeped twice (or where fine colours are wanted, thrice) in this alumino-oily soap appears to be then fit for maddering and to retain the colour in great perfection.

To give a full dead-red like that of the India handkerchiefs, Berthollet directs that the cotton should first be boiled in lime-water; then steeped in the bath of soda, oil, and gastric liquor of sheep or other ruminating animals; washed; steeped in a mordant of acetite of alumine (made by alum and sugar of lead) and lastly maddered. In this case the finishing process is not required. The colour thus produced is a full red without lustre, and the deadness of colour appears to be owing to the lime-water.

Cotton dyed red may be brought down through all the intermediate shades to a pale orange, by steeping for a longer or shorter time in nitrat of tin. As a general rule, to give the

brighter colours the cotton must be but moderately oiled and galled, steeped for a length of time and often in alkaline leys of the weaker sort, largely alumed, dyed with the best and brightest madder, and at the last long and plentifully soaped.

Such in a general way are the processes by which the red colour of madder may be made durable on cotton and linen. The shades of degraded red producible by adding any iron solution to the aluminous mordant are endless. It may only be added that for the sake of economy the same bath may often be used with advantage, both for the fine bright reds and for the violets, wine colour, and other darker shades, by employing for the former the madder bath when first warm and fresh, and for the latter the same bath when fully boiled, where the dun yellow part of the madder begins to prevail, and in which it can produce no material injury to the intended colour.

Of Cochineal Scarlet and Red.

Whoever casts his eyes on a piece of broad-cloth dyed in the most perfect manner with the fine or cochineal scarlet, must be struck with its transcendent beauty and lustre, and acknowledge it to be one of the finest efforts of the art of dyeing.

The scarlet dyeing in general makes a distinct branch of trade, the materials being of that delicate kind as easily to be hurt by accidental admixture of other colours, and part of the apparatus being somewhat different from that of common dyeing. The boiler in which the cochineal bath is made is generally of tin or strongly tinned copper, for as a solution of tin is the mordant employed, no harm can arise from its being in contact with the same metal, but copper might be somewhat acted on in the process and the dye injured. The quality of the water is also of importance here, which should be soft and pure, for hard water tends to produce a rose colour, which however is corrected by boiling bran or starch in it.

Cochineal (the peculiar nature of which is described under that article) contains a vast quantity of colouring matter in proportion to its weight, and yields it very readily to water cold or hot. The infusion of cochineal is naturally of a fine crimson, and is entirely an adjective colour, but with a mordant it fixes on woollen and silk with great firmness, but weakly and with difficulty on linen and cotton.

Alum appears to have been the mordant first employed to fix the colour of cochineal on wool.

^a Phil. Mag. vol. 18.

^o An. Chim. tom. 41.

It does not sensibly alter the natural tint, as it gives a deep and durable crimson. It even restores the crimson to cloth dyed scarlet by the compound tin mordant.

The astonishing effect of all the solutions of tin in heightening the colour of cochineal, appears to have been first discovered and put in practice by one Kuster, a German, who settled at Bow, near London, about the year 1543,^p whence scarlet was called the Bow dye in this country. It has been generally supposed that the change of the natural *crimson* of this drug to *scarlet* was owing simply to the effect of the nitro-muriat of tin, which is the common solution used by the dyers, but Dr. Bancroft has fully proved (as indeed is acknowledged by Berthollet in his second edition) that this is a mistake, and that the nitrat or muriat or nitro-muriat of tin used alone only heightens the colour of cochineal, but does not materially change its natural crimson; but that it is the addition of *tartar* to the tin solution which converts the crimson to that fiery bright scarlet for which this dye is so preeminently valuable. Now as scarlet is a colour composed of crimson and yellow, and as tartar changes the cochineal crimson to yellow, it may be inferred that the simple effect of the tartrate of tin (which salt is formed by double decomposition when the nitro-muriat of tin and tartar are mixed) is that of adding a yellow. This position Dr. Bancroft found by experiment to be accurate; for when cloth was dyed with cochineal, and the tartrate of tin singly made by dissolving this metal in the tartareous acid, the dye was a full scarlet. An equal effect was produced by substituting lemon juice or else the pure citric acid to the tartareous. Berthollet also found that on dyeing three samples of cloth, the first with nitro-muriat of tin, tartar and cochineal in the proportions commonly used; the second with the same ingredients but with a double proportion of tartar; and the third omitting the tartar, that the first sample was of a full scarlet, the second a scarlet more inclining to yellow, and the third a crimson.

The solution of tin usually employed by the dyers is prepared in the following way. Dilute nitric acid of the kind called *single aquafortis* is the acid used, and may be made by proper management to take up about one-eighth of its weight of tin. A small quantity of tin (previously granulated by being poured when melted into cold water, kept briskly agitated with a bundle of rods) is put into a glass vessel, to

which is added the aquafortis mixed with from $\frac{1}{16}$ to $\frac{1}{8}$ of its weight of common salt or sal ammoniac, and still further diluted with water. A strong action begins almost immediately, without artificial heat, and it is the business of the preparer to keep this action as moderate as possible, by setting the vessel in a cool place and adding only small quantities of tin at a time, in proportion as the last added quantity is dissolved. By this method the acid becomes fully saturated with oxyd of tin, whereas if the heat generated in the process is not checked, or if the acid is too strong, the greater part of the tin will remain undissolved in the form of a white oxyd. Even when well made, the solution (or *spirit* as the dyers call it) is apt to coagulate by mere keeping and to deposit the oxyd of tin, which it cannot again be made to take up. The use of the muriat of soda or ammonia is to prevent the spontaneous separation of the tin. The muriatic acid singly is a much better solvent for tin, taking up a large quantity and retaining it for any length of time, but the simple muriat of tin, and indeed of many other metals, is found to have a very corrosive effect on the fibres of wool, and even (in a less degree) on those of linen and cotton.

To preserve the muriatic acid in the solution, and at the same time to combine it with some other acid which has not such a corrosive effect on cloth, Dr. Bancroft recommends the murio-sulphuric solution of tin, as equal in efficacy to the nitro-muriatic and much cheaper. For this purpose 14 ounces of granulated tin are to be added to a mixture of two pounds of sulphuric acid of ordinary strength, with three pounds of muriatic acid. No particular precautions are required in making the solution, which will be equally permanent with or without artificial heat.

As the state of oxygenation of all metallic solutions, and particularly of those of tin, very materially affects all their chemical properties, a few observations on this subject may be mentioned after describing the process of scarlet dyeing.

Woollen cloth is generally dyed scarlet in two operations, though a single one will suffice, but in general is less convenient. To dye a hundred pounds of wool, 8 or 10 pounds of tartar are first put into the boiler with a sufficient quantity of soft water, and 6 or 8 ounces of cochineal. Immediately afterwards 10 or 12 pounds of the nitro-muriat of tin are added, and when the mixture is ready to boil, the cloth

(previously wetted) is put into the dyeing liquor and turned through it by a winch for an hour and a half, the liquor being kept boiling the whole time. The cloth is then taken out and rinsed, and is found to have acquired by this first operation a full flesh colour. The boiler is emptied, and again filled with fresh water, and when nearly boiling, from five to six pounds of powdered cochineal (according to the depth of colour wanted) are thrown in and well stirred, after which about 10 pounds more of the solution of tin are added, and the cloth is then put in and turned through the boiling liquor at first briskly, afterwards slowly, for half an hour. It is then washed and dried in the usual manner. The average proportion of cochineal to dye a full scarlet is an ounce to a pound of the cloth, and hence from the high price of this article the cochineal dye is one of the most (if not the most) expensive of all the processes in the whole art of dyeing.

This dye may be given apparently with equal effect by a single process, that is, by mixing together the whole quantity of tartar, solution of tin, and cochineal at once, and passing the cloth through the bath for a sufficient time; for the affinity between the wool, and the mordant, and the colouring matter is so strong, that this triple union takes place at once, and with great force. Or the whole of the tin and tartar may be used in the first operation, and the whole of the cochineal in the second.

It may also be observed that a great difference is found in the respective proportions of these ingredients, used by different dyers.

When a very bright flame-coloured scarlet is wanted, a little yellow fustic is added to the first bath, or else some turmeric is added to the cochineal in the second. This gives both a yellow ground and mixes a portion of yellow with the scarlet. These additions are discovered by cutting the cloth, for in this case the inner part will be found dyed simply yellow, the reason of which is, that in the common process the cochineal does not penetrate the inner part of the cloth, so that where these yellows are not used, this part remains white. If the scarlet has too much of an orange tint, this is corrected by afterwards boiling the cloth in hard water, or one that contains any earthy salt.

It is on account of the ease with which almost any alkaline or earthy salt counteracts the yellow part of all these colours, that scarlet cloth is always changed more or less to a rose or crimson by the process of fulling. Hence too

the scarlet is always given to wool after it is manufactured, and not in the state of yarn.

After the full scarlet has been given to the cloth, the liquor still retains part of the cochineal with a large portion of the mordant, and this is used for the lighter dyes, or with the addition of fustic, madder, and other ingredients, it is employed for a vast variety of mixed or degraded reds, orange, &c. Much technical skill seems to be required to make the utmost advantage of these residues, which are still very valuable.

It does not exactly appear in what state of oxygenation the common dyer's solution exists, but probably before the colour is completely brought out, the metal is oxygenated in the highest degree. The nitric acid indeed when used alone, if weak and if the solution be made very slowly, and without heat, is found by Proust to contain the *sub-oxyd* of tin, or this metal in a very low state of oxygenation; for it is only in this state that it remains soluble, and when more highly oxygenated it totally separates from the acid in the form of a white perfect oxyd.

But the muriat of tin on the other hand may contain either the perfect oxyd or the sub-oxyd, the latter is the case when the solution is recently made, and has not been exposed to the air, from which it greedily attracts oxygen, but in this case without separating from its acid solvent.

The muriat of tin, loaded with metal by being boiled on more than it can take up, if cooled to the freezing point gives abundance of crystals, which however again liquefy at a summer heat, and hence must be kept in a cool place. Mr. Hauffman^a dissolved one ounce of this salt recently made in 8 pints of water, to which he added with constant stirring an infusion of 2 ounces of cochineal in 8 pints of water. A very deep violet coloured precipitate subsided, (a mixture of the sub-oxyd of tin with the colouring matter of the cochineal) which however by exposure to air gradually turned to a fine carmine: but kept close in a bottle no such change of colour took place. If the solution of tin is exposed to air before mixture with the cochineal, the precipitate becomes carmine much more speedily, as it already contains nearly oxygen sufficient for this purpose. The carmine-coloured oxyd turns somewhat crimson by the addition of ammonia, but returns to carmine when this alkali is again evaporated.

If a carbonated alkali is added to the muri-

^a Jour. de Phys. tom. 48.

ated *sub-oxyd* of tin, a carbonated *sub-oxyd* is separated, which is very greedy of oxygen, but if added immediately to dilute nitrous, or dilute sulphuric, or acetic acid, dissolves therein with ease and produces a nitrated, sulphated, or acetited *sub-oxyd* of tin. The nitrated *sub-oxyd* however shews different properties from the common dyers solution, producing only a violet or dull crimson with cochineal, which afterwards heightens in colour by exposure to air.

An acetited *sub-oxyd* of tin is also formed, as Mr. Hauffman has also observed, by adding equal parts of crystallized muriat of tin and acetited lead with sufficient water, and decanting the clear liquor from the muriat of lead formed by double affinity. This liquor to retain its state of *sub-oxygenation* should be kept in a close-stopped vessel, and when mixed with cochineal gives also a deep violet precipitate, which requires an exposure of some weeks before it entirely changes to red or carmine.

Mr. Hauffman proposes the acetite of tin as a mordant in topical dyeing, either to calico or any other substance, and with any suitable dyeing drug. As the acetites are much better mordants for printing than the salts with the three mineral acids, the acetite of tin may perhaps be of use in this species of dyeing, but when prepared with acetited lead there is always a danger of some lead being mixed with the solution of tin, which may materially and unexpectedly alter and degrade the colours.

Crimson is given to cloth in two ways, either directly, or by changing the scarlet dyed in the manner already described. All earthy salts and especially alum, will change the cochineal scarlet into crimson, when boiled with it for an hour or more. Very hard water will produce the same effect without any addition. Hellot found that muriat of ammonia with a little potash gives almost immediately a beautiful rose colour to scarlet.

To dye cloth directly of a full crimson the same materials are used as for scarlet, but less of the tin solution is employed, and alum is added to the bath. They are sometimes finished with litmus and potash, which add much to the lustre and depth of colour, but this finish is only superficial and extremely fugitive.

Silk is dyed crimson in the following way. It is first prepared by boiling with soap as usual, but not so compleatly, as it is rather of service to leave a shade of the natural yellow, which it is the object of the soaping to destroy. It is then alumed very strongly and for a considerable

time. The dyeing bath is made with the usual materials for scarlet, that is, solution of tin, tartar, and cochineal, but it is also found expedient first to add some galls to give a basis to the silk to receive the cochineal dye. The particular management in the cochineal bath need not be described.

The crimson is often slightly browned by passing the dyed silk through a weak bath of sulphat of iron. If an approach to flame colour is wanted, the silk is finished with fustic.

It is impossible to dye silk scarlet by the same method as that employed for woollen cloth, for instead of this fine colour, the silk treated in this way would lose its lustre and only take a very faint dye. It appears still to be a point hardly attained, though very desirable, to give to silk a full durable scarlet equal to that on woollen.

Cochineal is very seldom used to cotton or linen, as no method is yet known (except as a lucrative secret to one or two individuals) of giving a good cochineal scarlet to these substances; and in general the effect of this dye on linen and cotton is not so much superior to the cheaper madder and other colours as to be at all adequate to the cost of cochineal.

Of Reds from Kermes, Coccus Polonicus, and Gum-Lac.

These three substances all give different shades of red, of at least as much durability as those of cochineal, but much less brilliance, and they are so totally disused in this country, and nearly so in other parts of Europe, that a very short notice will suffice.

The Kermes (Coccus Illicis) is a small insect found in many parts of Asia and southern Europe. (See the article *Kermes*.)

It gives a high red both to water and alcohol.

Wool intended to be dyed with it is first boiled in bran water, then alumed with alum and tartar, to which four starch liquor is often added. In the dyeing process nearly equal parts of kermes with the cloth are required, whereas cochineal need not be more than about $\frac{1}{16}$ of the wool. The dyed cloth may be finished with soap water, which gives a crimson cast.

The dye of kermes is so durable that tapestry 200 years old was observed by Hellot^r to have lost nothing of its depth of colour, during so long an exposure to sun and air. The kermes scarlet was anciently called in France *Ecarlate de Graine* (or sometimes *Venice Scarlet*.) It may be prepared in the same way, generally, as the cochineal scarlet.

The kermes red is much less lively than that

^r Mem. de l'Acad.

of cochineal, and tends more to the colour of blood. It has the great advantage however of resisting soap and other substances very well, so that grease spots may be got out of kermes-dyed cloth without any detriment. On the whole it seems very worthy to be retained. Silk has never yet been made to take more from it than a rusty red.

The Coccus Polonicus is a small round insect, found adhering to the roots of a species of the polygonum. It is not known to be employed in the dye-houses in Europe, but is used in Poland and countries where it is indigenous, and also in Turkey.

Lac or *Gum Lac* (which see) is a gummy-resinous substance somewhat resembling beeswax, occasionally used in dyeing, though rarely, if ever, in this country. A part only of the colouring matter is soluble in water, and it gives a dull red but very durable dye, which has been used with advantage mixed with cochineal.

Of Reds and Violets from other substances.

Many of the lichens are capable of giving different shades of purple, red, violet and the like, and these colours are so far substantive that no mordant will sensibly encrease their durability, but they are all more or less fugitive, and can only be used with propriety to give a gloss or finish to articles already dyed. The substance called *turnsole*, *archil*, or *litmus*, is the best known of all the lichens, and is used pretty largely especially in silk-dyeing. (See the articles *Lichen* and *Litmus*.)

Carthamus or *SAFFLOWER* is another beautiful and delicate red, verging towards orange, sometimes used in dying, but is fugitive. It is the colouring material of the rouge used as a cosmetic.

Brazil Wood or *Fernambouc* is an article of much more importance than any of the preceding, and is employed very largely in dyeing. The natural colour of this wood is a purple-red, and by different mordants it may be made to assume most of the shades of colour connected with red.

The great inconvenience attending the use of Brazil wood is its fugitive nature, and no method seems yet to be found which will prevent its loss of colour by considerable exposure to air, and its degradation by soap and alkalies. Hence the Brazil wood colours are sometimes called *false* dyes, being much inferior in durability to the *true* dyes given by cochineal or madder. The colour of Brazil wood requires a mordant, which is usually alum with a small quantity of tartar. This both gives a certain

durability to the dye and turns the natural purple to a clear red. Too much tartar gives a yellow tinge. It requires long boiling to exhaust this wood of its colouring matter. Nitro-muriatic of tin is also an useful mordant, and gives much brilliance to the colour.

Silk is dyed crimson with this wood, and the colour is nearly as beautiful as the cochineal crimson, though much less durable. The silk is first prepared with white soap, then alumed, and then passed through a strong decoction of the wood. When the shade is too red it is brought to a crimson by finishing with a weak alkaline bath. When a very deep crimson is wanted, logwood decoction is mixed with that of the Brazil wood. Silk will not admit of the tin mordant with this wood any more than with cochineal; owing, as appears, to the too rapid precipitation of the colouring particles before they can properly fix themselves to the fibres of the silk.

Cotton takes the Brazil wood colour with difficulty, and this is always liable to be changed by soap.

The most permanent Brazil wood colours are those in which the natural purple-red is changed to orange or yellow by acids, but it is chiefly for the red, crimson, and purple hues that this dye would be the most valuable, if any means could be found to render them permanent.

Logwood or *Campeachy Wood* is, like the former, a very hard heavy wood of a deep red or orange red colour, and largely employed in dyeing. The chemical properties of logwood will be described under that article.

The colour of logwood is extracted by boiling with water, and it then forms a deep violet red or purple decoction, like Brazil wood made yellow by acids and deepened by alkalies. The colour of logwood is more violet than Brazil wood, and it also contains much more gallic acid, and hence its use with iron liquor in all black dyes, as has already been mentioned. The red or purple of logwood is not permanent, but with alum and tartar it gives a fine deep violet, and is often used for this purpose. A fine blue is also given by dissolving verdigris in the decoction of this wood.

Silk is dyed violet by logwood on an alum mordant.

Of Fawn, Buff, or Nankeen Colour.

Almost all vegetables contain in the bark or cortical part a colouring matter of a shade approaching either to brown or yellow with more or less of red, which has a certain and often a

very strong affinity with the fibres of wool, linen and cotton, and may even frequently be fixed permanently in these substances without any mordant. A great portion of this colouring matter is pure tannin, the colour of which is naturally of a light dun yellow. It is also often mixed with gallic acid, and hence these substances may be made to produce an infinite variety of shades composed of brown-yellow and black in different proportions by the use of an iron mordant. Of these the commonest are walnut husks and sumach.

The outer bitter husk of the *Walnut* is well known to be green at first, but by exposure to air it turns of a deep brownish-black, so as to give the fingers a very durable brown stain. The decoction of this substance slowly evaporated forms successively a number of pellicles at the surface, which when well washed are nearly black, and in which nearly the same change seems to have taken place speedily as occurs by long exposure in a moderate temperature. Alkalies do not sensibly alter the colour of the decoction, but acids brighten it and give a decided yellow cast. Alum gives a very small fawn coloured precipitate; sulphat of iron turns it black, and even oxyd of iron boiled in the decoction is dissolved therein and forms a dark ink.

The root and bark of the walnut-tree gives a decoction much resembling the fruit-husk.

The colouring part of this substance has a strong affinity to wool, uniting with it nearly as strongly without as with mordants, and giving it a very fast buff or fawn colour; but alum encreases the density of the dye and makes it somewhat lighter in colour.

Walnut-husk forms an excellent dye for wool both by itself and as a basis for other colours. The husks will keep for more than a year in tubs covered with water.

Sumach is a very extensively useful article of dyeing both for all the fawn and buff colours, and with an iron mordant for various shades of grey to black. It requires a mordant to fix it on stuffs, but then is very durable. With alum it gives a greenish yellow, with a mixture of acetite of alumine and iron liquors it gives a grey, and with iron liquor alone, a black.

A good, bright, and durable nankeen colour is given to cotton by iron liquor, the cotton being previously prepared with dung and alkali, nearly as in the first part of the Turkey red process. This method of nankeen dyeing, as given by Mr. Brewer,* consists of eight opera-

tions, the first, second and third of which are to give the cotton yarn a preparation in a bath of sheep's dung and soap; the fourth a bath of pearlash; the fifth is the dyeing with iron liquor; the sixth a pearl-ash bath; the seventh a souring with dilute sulphuric acid, and the eighth, a finish with soap. The iron liquor is chiefly the aceto-tartrate, or that which the calico-printers mostly prepare by dissolving iron in an acid made of any fermented materials, or of pyroligneous acid, or alder bark and buds, or many other vegetable matters that either contain a naked vegetable acid, or are able to produce one by fermentation. The cotton is first soaked in this acid iron-liquor, after which it is supersaturated with pearlash, so that probably a solution of oxyd of iron in carbonated alkali is formed, which finishes the dye and gives it durability. The use of the sulphuric acid is to dissolve out all the iron that only loosely adheres to the stuff, which being chiefly the red oxyd, the colour becomes clearer and brighter by the loss.

Of Green.

Though nature abounds with this colour, it is rather singular that no vegetable has yet been discovered capable of giving to cloth of any kind a green of any tolerable permanence. This dye is therefore always a compound colour formed in dye-vats either by putting a yellow on a blue ground (which is the commonest) or a blue on the yellow ground, or by first mixing the blue and yellow materials and dyeing with these as with a simple colour.

Much nicety in the practical part of dyeing is shewn in the proper raising and fixing of this colour, and many processes of particular excellence are carefully confined within the walls of different manufactories. The general methods however are simple and well known.

The common and most permanent green on woollen cloth is given in the following way. The cloth previously dyed blue in the indigo vat (with more or less body of colour according to the body of green required) is first well scoured, then dyed in a bath of weld or any other yellow dye with alum and tartar, almost exactly in the way followed for the simple yellows, but with a greater quantity of the yellow materials than would be required for the yellow alone of equal body. Very deep greens have sometimes a slight brown or kind of burnish given to them by adding to the bath small quantities of logwood and sulphat of iron. For silk the process is reversed, being first strongly

* Dublin Society Transactions, vol. 1. or Phil. Mag. vol. 17.

alumed, then dyed yellow with weld, and afterwards finished in the indigo vat. It is much more difficult to fix the colour evenly on silk than on wool, for the silk when strongly alumed takes the dye so rapidly that it is apt, without great care, to become wavy or spotted.

Another kind of green dye, more bright and beautiful than the last but not quite so permanent, is the *Saxon Green*, so called from the blue part being given by the Saxon blue or sulphat of indigo. This colour may be dyed by first giving a ground of Saxon blue, then aluming, and then passing the cloth through a yellow bath. Fustic is commonly preferred as the yellow material, as being less altered by the adhering acid of the sulphat of indigo than weld or the other yellows. To correct this effect of the acid and enable quercitron to equal the fustic in this respect (whilst its natural colour much excels it) Dr. Bancroft advises after the cloth has received the blue to mix chalk with the alum mordant to neutralize the adhering acid, before the yellow is given.

The Saxon green may also be given in a single bath: for which purpose the cloth is first alumed and well rinsed; then a strong decoction of fustic is made, to which when cooled to a blood heat is added the sulphat of indigo, and the cloth dyed therein with the usual precautions. Beautiful Saxon greens may be dyed in a still more expeditious way, according to Dr. Bancroft, by using the compound alum and tin mordant. The process he advises is the following. Put into the boiler 6 or 8 lbs. of quercitron bark to every 100 lbs. of cloth, boil with sufficient water, then add 6 lbs. of the *murio-sulphat* of tin (in preference to the nitro-muriat) and 4 lb. of alum: when these have boiled five or six minutes, lower the heat with cold water to blood warm, after which add as much sulphat of indigo as may be thought necessary for the intended depth of colour, and then dye the cloth in this bath with proper care.

Silk, cotton, and linen are dyed green in the same general way, but with considerable variation in the detail of the different processes, and the same difficulties that attend the fixing a single colour on these substances apply to the compound colour.

The most beautiful green hitherto known, and one that resists the action of light and air perfectly well, is given by the combination of Prussian blue and yellow, but like the simple blue from this colouring matter it is destroyed by soap and alkalies. It is given to cotton by first dyeing it olive with weld, or any other

yellow dye, and a compound mordant of alum and iron, and then raising the green by prussiat of potash in the manner described under the Prussian blue colours. In this process, as Berthollet observes, there seems to be a mutual distribution of the mordants and colours, the Prussian colour taking the iron and becoming blue, whilst the alum and weld remaining in the olive, form a fast yellow and unite with the blue into a fine green.

The only simple green commonly used is that of the carbonated oxyd of copper precipitated from verdigris by an alkali. A solution of verdigris is made in vinegar, and a few hours before dyeing a solution of as much pearlash as verdigris is added to it, the mixture is heated, and the cotton previously alumed is passed through this bath. The colour thus given is a soft apple-green.

Of other Compound Colours.

By the mixture of red and blue in different proportions, violets, purples, lilacs, and vast number of other agreeable dyes are formed, but of which it would be tedious to attempt an imperfect detail. In like manner the coquelicots, brick-colours, chefnuts, cinnamons, &c. are formed from the intermixture of red and yellow. It may be added that in cotton dyeing, advantage has been taken by Chaptal of the difficulty with which cotton strongly alumed and oiled (as for the Turkey red) imbibes watery liquids, to give a singular variety of shade in the same piece, according to the direction in which it is seen, and which gives the effect of a number of small irregular streaks over the surface. If cotton previously oiled, alumed and galled be only slightly passed through a bath containing sulphat of iron, the nap of the cloth alone becomes entirely black and the thread grey: if this be afterwards maddered, the thread becomes red and the nap violet, which produces an agreeable changeableness of colour as seen in different lights.

OF CALICO PRINTING.

To apply a coloured pattern on a white or coloured ground, only two general methods appear practicable, the one, to weave the pattern into the cloth with threads dyed of the requisite colours, the other to devise some method of topical dyeing, which shall, like a picture, confine the desired colours to those parts only that are figured by the intended patterns. The former is the delicate business of the embroiderer or the tapestry weaver; the latter is the ingenious art of the calico-printer.

The history of this art and the detail of the

vast variety of processes employed in producing the various coloured patterns, it would be superfluous to enter into, especially as most of what has been described of general dyeing applies (as far as the chemical principles of the art are concerned) to topical dyeing. A few examples therefore of the peculiar manipulations of calico-printing will suffice.

It is particularly, though not entirely, with the adjective colours, or those that require a mordant, that calico-printing is concerned, as this very circumstance affords a ready method of giving a permanent colour only to the pattern part; for if this latter only is impregnated with the mordant, and the whole cloth is then uniformly dyed, the natural effect of exposure to sun and air, will be to discharge all the colour from every part of the cloth except where it had previously received the mordant, and thus a coloured pattern will be produced on a white ground.

This partial application of mordants therefore followed by general dyeing, constitutes the greater part of calico-printing, besides which, however, a further variety of application often occurs, as sometimes colours themselves are painted or pencilled in to assist the general effect, which therefore require no subsequent operation; and occasionally other contrivances are used to fix, or alter, or discharge colours, according as the proposed pattern may require it.

Two mordants are more particularly used by calico-printers, though equally serviceable in general dyeing, the one is acetite of alumine with a portion of alum, the other is a solution of iron in some vegetable acid.

The acetite of alumine is always made by double decomposition of alum and sugar of lead, but the proportions of each vary much according to circumstances, and probably to the fancy of the colour-mixer. In general three pounds of alum (or in that proportion) are thrown into a barrel, and when dissolved, a pound to a pound and a half of sugar of lead are added, and the whole often stirred for two days. On settling, a clear liquor is found at top which consists of acetite of alumine, but still containing much undecomposed alum, and a dense white sediment remains at bottom which is sulphat of lead. The clear liquor is the part used for the mordant, but previously two ounces of pearl ash and as much chalk are added, more entirely to neutralize any excess of acid, and partly to decompose the solution; for though the mordant must be in a saline state entirely to fix itself to the fibres of the cotton, it should seem that

the true intermede between the cotton and the dye is the alumine, and not the acids that hold it in solution, and hence the weaker the adhesion of these is to the alumine, and the stronger will be the triple union between the colour, the earth, and the cotton fibre.

The other mordant constantly in use with the printers is a solution of iron in vinegar, soured beer, pyroligneous acid, or other vegetable acids, and which therefore is chiefly an acetite of iron mixed with a portion of tartrate, perhaps gallat, and other salts of this metal.

To make these mordants fit for printing, and give them such a consistence as will enable them to dry in a figured pattern without running into the adjoining parts, they are thickened with paste to the consistence of jelly; and when to be used, this jelly is squeezed through a very fine sieve by a particular and simple contrivance, on the surface of which it lies as a thin coating convenient to be transferred to the printing blocks.

The mordant, when naturally colourless, is a little tinged with Brazil wood (which being a very fugitive dye does not impair the general effect) that the workman may see the impression on the cloth and fix the pattern with accuracy.

The instrument by which the impression is given (or what answers to the types in the printing of books) is a piece of hard wood, generally holly, about a foot long, on which the pattern is carved, nearly as in wood engraving, and is strengthened at the back with a thicker piece of oak glued on. The parts of the pattern that are to receive a large body of colour, and consequently require a corresponding quantity of mordant, are given by pieces of old hat inlaid into the block which are found to take up the mordant in a more uniform way than any other material. Of late years also some of the finer patterns are given by sheet-copper fixed on a block like fillagree work, which gives a finer and sharper line to the figured pattern. Fine work is sometimes given still more expeditiously by engraved copper-plate and the rolling-press as in common picture engraving.

The general process of the simple kind of calico-printing therefore is the following: the cotton cloth, previously bleached with alkali and much washing, and calendered to smooth the surface, is stretched on a long table covered with woollen cloth, when the printer first lays the block on the sieve that contains the mordant, then applies it steadily on the cloth, and strikes it a smart blow on the back with a wooden mallet to give a strong impression.

This he repeats successively, each time carefully laying the block in the proper direction so as not to overlap the last impression, till the whole is finished.

In this way the patterns are impressed with one or more kinds of mordant as may be required, after which the cloth is strongly dried in a stove room, which both fixes the mordant more firmly to the cotton, and volatilizes much of the acetous acid in fumes very sensible to the smell. When dry, the cloth is taken to a cistern containing very warm water, in which cowdung is diffused, and there it is worked about to dissolve out the paste and other superfluous part of the mordant, sufficient being yet left firmly united to the fibres of the cloth to fix the dye in the subsequent process. The cloth is then rinsed and thoroughly cleaned, after which it is dyed in the usual way. The cloth comes out of the dying cistern entirely coloured (yellow for example when the dye has been weld) it is then again washed with water, boiled with bran and water, alternating with exposure to air on the bleach-field, and other bleaching processes, till at last all the colour of the ground has disappeared, and that only remains which has been fixed to the pattern by the mordant.

The above is the simplest process, that is, in which all the mordants are laid on first, and the colour is given by a single dyeing afterwards, and by merely varying the mordants a considerable variety of shades may be given. Thus for example, if one pattern be printed with the aluminous mordant alone, a second with a mixture of the former mordant with iron liquor, a third with iron liquor alone, and a fourth with iron liquor and galls, and the piece be afterwards dyed with quercitron or weld, and the ground bleached in the usual manner, the first pattern will be of a pure yellow, the second will be olive, the third of a dark drab colour, and the fourth nearly black, whilst the ground will be white.

Cloth that has been thus printed with one course of colours is often subjected to a similar process for a different course with another dye, where the intended pattern requires a great variety of colours.

Thus when all the reds, purples, browns, &c. have been given by a course of madder, the cloth with part of the patterns thus finished, may be made to undergo a course of mordants to be afterwards dyed with quercitron for other parts of the pattern. In this case however much judgment is required to employ only those successions which will not materially injure each

other. It might be at first supposed that when a pattern dyed red (for example) with madder and an alum mordant came to be immersed in a decoction of weld without any fresh mordant, that the former would not be at all affected by the latter, or at least that the effect would soon be destroyed by bleaching; but this is not found to be altogether the case, for adjective colours appear to have also their *relative* affinities for mordants, therefore as a fast madder red is a compound of madder and alumine, if madder has a less affinity for alumine than weld, the colour will be in part decomposed, and some of the weld will displace a portion of the madder. Hence the colour will be changed into a triple compound of madder, weld, and alumine, and the dye proportionally altered. It appears therefore that in printing successive courses of colours attention should be paid to print first those whose affinities for the mordants are the strongest, and finish with the weakest, unless indeed (which is sometimes the case) the change produced by the intermixture of colours be a part of the desired effect. But much remains to be done towards a rational explanation of the complicated affinities and mutual action of mordants and colouring matter, and of the apparently slight variations by which, however, the skilful printer is enabled to produce effects which at present a person could hardly hope to imitate without a large share of practical experience.

Another part of calico-printing is the impression of *colours*, for hitherto that of mordants only has been mentioned. In this case also, as in general dyeing, the substantive colours do not, and the adjective colours do, require to be previously mixed with their proper mordant. Pattern colours are applied either by the block (as the mordants are) or by pencilling or painting. In the latter case the colour is thickened not with paste but with gum arabic or senegal, and it is applied with a camel's hair brush. The pencilled colours require no further dyeing operation, and are only finished by washing and drying, so that it is usually the last parts of the pattern that are given in this way.

Indigo is the only substantive colour used for pencilling, but here a very great difficulty presents itself; for indigo (as already mentioned in describing the blue dye) is only a fast colour when in its disoxygenated state, in which it is yellow or green; but when much exposed to air, as can hardly be avoided in the slow and minute process of pencilling, part of it returns to the blue or oxygenated state before it has properly fixed itself on the stuff, and this por-

tion is carried away in the subsequent washing. It is therefore very seldom that the pattern of a whole piece can be indigo-penciled with the same uniformity with which some of the other colours are given. The solution used for this purpose is usually made of a large proportion of indigo dissolved in potash, rendered caustic by lime, to which is added orpiment for the deoxygenation of the indigo. This latter effect is also often produced wholly or in part, by the cheaper kind of raisins. The solution is then thickened by gum, and should be kept in a close stopped vessel, and no more exposed to air than is necessary for immediate use.

This indigo-blue is also often pencilled upon figures previously dyed yellow in order to produce a permanent green, but with some little injury to the yellow ground by the caustic alkali contained in the indigo solution.

Adjective colours are sometimes mixed with their proper mordant, and used in this state for pencilling without any other preparation. Such a mixture has therefore the effect of a substantive colour. Thus if a very strong decoction of weld or quercitron is added to a mixture of alum and sugar of lead, and the whole duly thickened, a yellow of a certain degree of durability is formed at once, and may be printed or pencilled on a white ground to produce a yellow, on an indigo ground to give a green, on a red madder ground to give an orange and the like.

It is found however that adjective colours when first mixed with their mordants, and then applied to cotton, have very little durability compared to that of the method of first applying the mordant thoroughly, and then the colour. This difference holds good in the general as well as topical dyeing of cotton and linen with all adjective colours, as has already been fully described, though with regard to wool it appears to be often a matter of indifference as to the fixity of the colour, whether the mordant and the dye are applied separately or united. Thus woollen cloth may be dyed with cochineal and tin, apparently equally well in one as in two operations. But as this does not hold with cotton it still remains a great object in calico-printing to discover some method of pencilling adjective colours so as to be sufficiently durable. It is also an additional difficulty to this object that the pencilled colours always require a very full body of colour, being generally applied

rather as finishing touches to the pattern than constituting any very large portion of it.

In many cases parts of the pattern itself are required to be white. Sometimes this may be done simply in the way that the ground is left white, that is by leaving these parts untouched by any mordant, so that when the whole is dyed with an adjective colour, subsequent washing and bleaching will destroy the dye on these untouched parts. This plan however is obviously inadmissible when the general dye is given by a substantive colour as indigo. In such cases some kind of covering must be applied to the white pattern parts to protect them from the dye, and hinder it from penetrating. In the East Indies wax is often used topically on the white parts for this purpose. In this country a mixture of pipe clay and paste is sometimes used. In these cases the cold indigo vat is of particular service, as the covering for the white is much less liable to be dissolved out, than in the usual way of dyeing in a heated bath.

But in the common method of producing white with adjective colours, the smaller parts of the pattern are seldom so well defined and thoroughly bleached as to render the work perfect. With every care some part of the adjoining printed mordant will often spread a little beyond its proper limits, and occasion a permanent soil on the white, besides that the removing some stains by bleaching, particularly those from the weld bath, is tedious and difficult. To remedy this therefore, and to give a perfectly clear and well defined pattern white to the parts without mordant, which so much improves the general effect, the bleaching power of acids has lately been much resorted to. Most of the acids possess this power, but the stronger mineral acids are so liable to affect the texture of the cotton when sufficiently strong, that they cannot be employed. Recourse therefore has been had to the stronger vegetable acids, and of these the *Citric*, either in its crystallized state, or merely as lemon juice concentrated by boiling, holds the first place, and this article has of late years been consumed by the printers of this country to a vast amount. It is usually applied by the block like the common mordants. The particulars of the preparation of the *Citric* acid are described under that article.

For some further observations on the nature of colouring matter see the article *Extract*.

EARTH. *Terre, Fr. Erde, Germ.*

While chemistry was under the dominion of fancy and metaphysics, before the establishment of the maxim that facts are to precede and serve as the basis of all reasonings in natural science, it was imagined that all material substances were ultimately resolvable into four simple bodies, viz. air, fire, water, and earth, which were hence called the four elements. The two first were avowedly almost wholly unknown, most liquids were supposed to be modifications of the third, and the solid particles of bodies were attributed to the last. Earth in this extended sense was chiefly characterized by the properties of hardness and solidity, and was subdivided into various species, according to the supposed modifications that it underwent. Thus the class of combustible bodies was imagined to contain more or less of an inflammable earth; the various metals were considered as abounding with a metallic or mercurial earth, and so on of the other great classes into which solids are divided. These several earths however were considered as only modifications of the primitive elementary one. Modern chemistry, though it has retained the term in a much more restricted sense than it was applied formerly, has yet included under it a sufficiently heterogeneous assemblage of bodies; a considerable portion of which may much more properly be considered as belonging to the class of alkalies.

The earths that are at present known are nine in number, namely, Silica, Zircon, Alumina, Glycine, Ytria, Barytes, Strontian, Lime, Magnesia. When purified by art from all foreign mixture they agree in the following properties. 1. they are of a snow-white colour; 2. are infusible by a very intense heat; 3. are not reducible to the metallic state by being heated in contact with combustible matter. Of these nine earths however the four last have all the properties of alkalies (whence indeed they have sometimes been called alkaline earths) not differing from potash or soda so much as these do from ammonia. If therefore we were to confine the term earth to the five first, this double advantage would accrue from the arrangement, that the two classes of alkalies and earths would each admit of a genuine chemical definition, which they both equally want at present.

If such an arrangement were adopted, the remaining earths would be thus characterized.

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They are infusible, and insoluble in water, and have neither taste nor smell: they exhibit neither acid nor alkaline characters: they combine with acids and with alkalies either pure or carbonated: they have no action on metallic substances and are incapable of assuming the reguline form.

A considerable stir was made a few years ago in Hungary, by the pretended metallization of several of the earths by M. M. Ruprecht and Tondi, till their experiments were repeated by Klaproth and others, and shown to be entirely fallacious. The chemists first mentioned took a small quantity of any earth, barytes for example, and having beaten it up with a little water and charcoal, smeared it on the inside of a Hessian crucible; the cavity was then filled with powdered charcoal, and at the top of all was placed a layer of bone-ash; a cover being then luted on, the crucible was exposed for three-quarters of an hour to a blast furnace, in which it was heated almost to a state of pasty fusion. When the contents of the crucible were examined, the barytes was found in part melted with the earth of the crucible, and containing from 2 to 4 per cent. of brittle metallic globules, which were supposed to have originated from a decomposition of part of the barytes. These globules however on analysis by Klaproth, proved to be nothing more than phosphuret of iron; the metallic part doubtless originating from the iron contained in the earth of the crucible, and the phosphorus from the bone-ash by means of the charcoal. That this is the true explanation of the appearance is evident from another experiment of Klaproth, in which he repeated the process of Ruprecht, only substituting a porcelain for a Hessian crucible; but the earth of this crucible contained no iron, and there was not the slightest appearance of metallic globules in the barytes which it contained. Further, the experiment was again repeated in a Hessian crucible, only leaving out the barytes, and the globules made their appearance as plentifully as when the barytes was present.^a

EARTHENWARE. See **POTTERY.**

EAU DE LUCE. This is a scented fagonule composed chiefly of liquid ammonia and oil of amber, and forms a white milky fluid. These two ingredients however, even if mixed by long agitation in a vial so as apparently to be perfectly combined, after standing for a short time

^a *Ann. de Chim.* x. p. 275.

separate from each other into two liquids, the upper of which is the principal part of the oil little altered, and the lower is the ammonia, retaining just enough of the oil to give it a wheyish appearance. The following is recommended by Macquer^a as an efficacious method of preparing permanent Eau de luce.

Take four ounces of rectified spirit of wine and dissolve in it ten or twelve grains of white soap; filter this solution, and then dissolve in it a dram of rectified oil of amber, and filter again: mix with this a few drops of strong liquid ammonia and shake the whole well together in a vial; then add a little more ammonia, and so on gradually till the liquor becomes of the consistence of cream. This method however often fails to produce the desired effect, the compound spontaneously separating after a few days: hence various other additions have been made by druggists with greater or less success, and some of the best of all are kept in a considerable degree secret.

The goodness of the following method is attested by an anonymous correspondent in Nicholson's journal.^b

"Digest ten or twelve grains of the whitest pieces of mastic selected for this purpose and powdered, in two ounces of alcohol, and when nearly dissolved add twenty grains of elemi. When both the resins are dissolved add ten or fifteen drops of rectified oil of amber, and fifteen or twenty of essence of bergamot; shake the whole well together and let the fæces subside. The solution will be of a pale amber colour. It is to be added in very small portions to the best aqua ammoniæ puræ until it assumes a milky whiteness, shaking the vial well after each addition." If upon the addition of the first drop or two of the tincture a dense opaque coagulated precipitate is formed, it is too strong and must be diluted with alcohol. About one part of the tincture to four of the ammonia will produce the required opacity.

EDULCORATION. *Abfussen*, Germ.

This term is applied in chemistry to the process of washing out from a precipitate any excess of acid or alkali or compound salt that may adhere to it. The usual way is to place the precipitate on a filter, and when nearly all the liquor has drained away from it, to fill up the filter again with clean and pure water, either hot or cold, and as soon as this has passed through to replace it with fresh, till the last portions that drain are wholly tasteless and pro-

duce no change on turmeric or litmus-paper. This method however is often less effectual, and is always more tedious than the process which is had recourse to at present. When the precipitate is deposited, instead of throwing it on a filter pour it into a large silver crucible and boil it with some water; after this withdraw it from the fire, allow it a few minutes to subside, and draw off the clear liquor; then add fresh water to the residue and again boil it, and proceed thus till all soluble impurities are got rid of. A single half-hour thus employed will finish more work than a whole day in the common method, and the necessary loss upon the precipitate is considerably less, which is a circumstance of no small importance to the accuracy of an analysis.

EFFERVESCENCE. *Aufbrausen*, Germ.

Effervescence is a rapid disengagement of gas taking place within a liquid. In consequence of this numerous bubbles rise to the surface, forming a head of froth and bursting with a hissing noise. There is some external resemblance between effervescence and fermentation, only the latter process is much slower and more durable, hence it was that the ancient chemists applied the term fermentation to all the phenomena which are at present denoted by effervescence, and this misapplication of the term irresistibly induced them to explain the two processes by the same theory. Hence salt of tartar, of wormwood, and in short all the mild alkalies, as well as the several varieties of carbonated lime, were ranked as fermentable bodies, and the muriatic, nitric, and sulphuric acids, the addition of which produced in them effervescence or fermentation, were called ferments; and as in these cases the ferment was an obvious acid, so they imagined that all real ferments were also essentially acids, but with their properties masked and obtunded by mixture with mucilage, &c.

The gas of effervescence is produced by single or double elective affinity; in the former case it is for the most part carbonic acid, in the latter it is either nitrous gas or hydrogen. It is manifest that the gas must have little or no affinity with the fluid in which it is immersed, in order to produce effervescence, hence it is that although carbonic and muriatic acids are both gasses, and are both extricated from their alkaline combinations by sulphuric acid, yet a solution of carbonat of potash in water shall produce a vehement effervescence with sulphuric acid, while muriat of potash in the same cir-

^a Chim. Dict. art. Eau de Luce.

^b Nicholson's Jour. 4to. vol. i. p. 167.

cumstances shall occasion none at all, the carbonic acid having little or no affinity for water acidulated by sulphuric acid, while the muriatic acid will combine with the same very readily.

EFFLORESCENCE. *Befschlag*, Germ.

Efflorescence is the formation of a powdery crust, or of minute spicular crystals on the surface of any substance. It is applied to two distinct phenomena, which it is of consequence to be aware of. Salts are either unalterable in the air, or they attract part of its moisture and are resolved into a fluid, or they yield part of their water of crystallization to the air, and are in consequence first superficially, and afterwards entirely reduced to powder. This effect, at least in its commencement, is called efflorescence, and such salts are denominated efflorescent: but there is another kind of efflorescence wholly distinct from this, as when we speak of the efflorescence of iron pyrites or of new mortar; in these cases it implies the appearance of a superficial covering of minute hair-like crystals, and is occasioned by the chemical changes that take place on the surface of the substance where these crystals appear. Thus sulphuret of iron is changed by efflorescence into sulphat of iron or green vitriol: whereas sulphat of soda when subjected to the efflorescence first mentioned, although changed in form remains the same in composition, except that it has lost part of its water. The one destroys crystals, the other produces them.

EGYPTIAN PEBBLE. See JASPER.

EISENKIESEL. See QUARTZ.

ELASTIC BITUMEN. See BITUMEN.

ELASTIC GUM. See CAOUTCHOUC.

ELEMENTS. *Uranfange*, Germ.

Modern chemistry does not acknowledge any particular number of elements, but freely admits into this class all substances that have not hitherto been decomposed. An element therefore is merely one of the last results of chemical analysis; and in denominating substances elementary or simple, we look upon them as such only with regard to the present state of chemical science. It is not probable that any one of the simplest bodies with which we are acquainted is really and essentially elementary, and it is at best needless to enter into an enquiry in which there are no facts to rest on for support.

ELEMI. The resin known by this name, improperly called gum elemi, is supposed to be the produce of a large tree, arranged in the Linnæan system under the name *Amyris Elemifera*, and concerning which we know little or

nothing, except that it is a native of Carolina and the warmer parts of America. But the true elemi, according to Geoffroy, comes from Ethiopia.

The colour of this resin is a light yellow inclining to green; it is firm on the outside, but internally is somewhat soft and adhesive; it has a bitterish flavour and a grateful fragrant odour not very unlike that of sweet fennel seeds. It comes to us in cylindrical pieces or cakes, covered with palm-leaves.

When distilled in a water-bath, elemi affords about $\frac{1}{16}$ of essential oil, in which all the fragrance of the substance resides, the remaining resin being entirely inodorous and brittle. Sixteen ounces of elemi give out to hot water about three drams of extract, and of the remainder fifteen ounces appear to be resin.

Elemi is a scarce and dear substance; it is used occasionally in medicine as a liniment, and is employed in the arts as an ingredient in some varnishes.

ELUTRIATION. *Verwaschen*, Germ.

This term is nearly synonymous with *washing* or *washing over*. It is a method of separating substances of different specific gravities from each other by means of water. For this purpose the mixture is stirred up briskly with water, and when the heavier particles have again fallen to the bottom, the turbid water containing the lighter ones still suspended is poured off into another vessel. By this simple method, a person accustomed to the business will separate three or four substances from each other with surprising exactness and expedition.

ELIQUATION. See SILVER.

EMERALD. Of this mineral we may distinguish the two following subspecies.

1. Emerald. *Emeraude verte*, Haüy. *Schmaragd*, Werner.

The characteristic colour of emerald is pure prismatic green of various degrees of intensity; the deep coloured varieties pass occasionally into grass and verdigris green, and the lighter ones into greenish white. It has hitherto been met with only crystallized. Its primitive figure is a regular hexahedral prism, the lateral planes of which are smooth, and the terminal planes rough. 1. Sometimes the lateral edges are replaced by secondary planes, forming a dodecahedral prism. 2. Or the solid angles are replaced by small triangular facets. 3. Or the edges adjoining to the base are replaced by planes inclined towards the axis of the crystal, the junction of which forms a terminal trunc-

• Haüy, Brochant, Jamieson.

eated hexahedral pyramid. 4. Sometimes the solid angles at the common base of the prism and its terminal pyramid (var. 3.) are replaced by small rhombs. 5. Sometimes the secondary planes of var. 3 are very narrow, so that the terminal edges appear only bevelled. The length of the prisms seldom greatly exceeds their diameter. The crystals are middle-sized and small, very rarely large, the greatest that has yet been found is about 6 inches long and 2 inches in diameter: they are always implanted and in clusters. The internal lustre is vitreous and shining, sometimes brilliant. Its fracture is small and imperfectly conchoidal, passing into obscurely foliated in four directions corresponding with the faces of its integrant molecule, which is an equilateral triangular prism, the lateral planes of which are squares. It is transparent or translucent, and exhibits a double refraction. Its hardness is somewhat superior to that of quartz, which it scratches with difficulty. Sp. gr. 2.72 to 2.77.

It is fusible but with difficulty before the blowpipe into a whitish glass; it melts easily without effervescence by borax. Its constituent parts, according to Vauquelin and Klaproth, are

	Vauq.	Klap.
Silex - - -	64.5	69.
Alumine - - -	16.	15.
Glycine - - -	13.	12.5
Lime - - -	1.6	0.25
Oxyd of chrome	3.25	0.25
Oxyd of iron -	0.	1.
Water - - -	2.	0.
	100.35	98.

It occurs in veins passing through argillaceous schistus, and is accompanied by calcareous spar, felspar, quartz, and iron pyrites. It is found at present only in Peru in the valley of Tunia or Tomana, between the mountains of New Granada and Pompayan, and in the province of Manta. Previous to the discovery of America, the emeralds of Europe were procured from Ethiopia.

Emerald is reckoned among the gems, and when of a fine colour and without flaws is highly esteemed. The large emeralds spoken of by various writers, such as that in the Abbey of Reichenau, of the weight of 28 pounds, and which formerly belonged to Charlemagne, appear to be either green glass, green fluor, or prase. The most magnificent specimen of genuine emerald was presented to the church of Loretto by one of the Spanish kings; it

consists of a mass of white quartz thickly implanted with emeralds more than an inch in diameter.

2. Beryl, or Aquamarine. *Emeraude vert-bleuâtre*, Haüy. *Edler Beril*, Werner.

Its colour is either mountain-green passing into apple-green, oil-green, greenish-white, honey yellow and wine yellow (the chrysolite of some authors), or celandine-green passing into smalt, sky, and very rarely ultramarine blue. Its colours are almost always pale: when two exist in the same crystal they generally are arranged in alternate layers. The primitive form and varieties of crystallization are those which have been already described in the preceding subspecies. The actual and proportionate length of the prisms in beryl is much greater than in emerald; the lateral planes are striated longitudinally, so as sometimes to give the prism a cylindrical appearance, and the terminal ones are smooth: the joints perpendicular to the axis are generally very distinct, most commonly they are plane surfaces, but sometimes the joints like those of articulated basalt are formed by a convex protuberance let into a cup-shaped concavity; another singular analogy between these two widely different minerals is, that a prism which at its lower end is solid, terminates occasionally in a brush-like extremity, composed of numerous small prisms. Sometimes a joint is so disposed that it is no longer perpendicular to the axis of the prism, in consequence of which an elbow is produced, as if the prism had been broken across and the pieces ill cemented together again. Sometimes again the axis of the prisms is perforated. The size of the crystals varies from capillary to 18 inches long by three or four in diameter. Its external lustre is shining and glistening; internally it has a brilliant vitreous lustre. Its cross fracture is between uneven and small imperfectly conchoidal: its longitudinal fracture is foliated. It is commonly transparent passing into translucent. Its hardness is the same as that of the emerald. Sp. gr. 2.68 to 2.72. It becomes very electric by friction.

Its constituent parts according to Vauquelin and Rose, are

	Vauq.	Rose.
Silex - - -	68	69
Alumine - - -	15	14
Glycine - - -	14	14
Lime - - -	2.	0
Oxyd of iron -	1.	1
	100.	98.

Beryl occurs imbedded in primitive rocks, also in veins accompanied by quartz, felspar, fluor spar, garnet, mica, and topaz. The finest specimens come from Daouria in Siberia: it is also found in the Uralian mountains, in Brasil, in Saxony, near the village of Barat in the south of France, whence very large but ill-coloured crystals have been procured, and occasionally in the highest mountains of Aberdeenshire. It is ranked by courtesy among the gems, but is in very small estimation.

EMERY. See CORUNDUM.

EMETIC TARTAR. See ANTIMONY, *Tartrate of*.

EMPYREUMA. *Brenzliche beschaffenheit*, G.

Empyreuma is that peculiar and mostly disagreeable odour and taste which almost all animal and vegetable substances contract while decomposing by fire, especially in close vessels. An oil appears to be generated during the dry distillation of all organized bodies, and this when scorched seems to be the immediate cause of empyreuma.

EMPYREUMATIC ACID. See ACETOUS ACID *empyreumatic*.

EMPYREUMATIC OIL. See OIL.

EMULSION. *Körnermilch, Saamenmilch*, G.

An emulsion is a white milky-looking fluid, caused by an imperfect temporary combination of oil with water by means of mucilage, fecula, gluten, gelatin, and the like. All the oily farinaceous seeds, such as nuts, almonds, linseed, hemp-seed, mustard-seed, &c. form an emulsion by simple trituration with water; yolk of egg, which is a natural compound of oil and albumen, makes a similar emulsion, and these are much slower in undergoing spontaneous separation than those emulsions all the ingredients of which are put together by art, as when we triturate together oil and gum-water, yet even these by continued agitation may be made to enter into pretty intimate combination.

ENAMEL. *Email*; Fr. *Schmelzwerk*; Germ.

The delicate and beautiful art of enamelling consists in the application of a smooth coating of vitrified matter (transparent or opaque, and with or without colour, figures, and other ornaments) to a bright polished metallic substance. It is therefore a kind of varnish made of glass, and melted upon the substance to which it is applied, and affording a fine uniform ground for an infinite variety of ornaments which are also fixed on by heat.

The general principles on which enamelling is founded are on the whole very simple, but

perhaps there is none of all the chemico-mechanical arts which requires, for the finer parts, a greater degree of practical skill and dexterity, and of patient and accurate attention to minute processes.

The concealment observed by those who profess this art is proportioned to the difficulty of acquiring it; the general chemist must therefore content himself with the general principles of enamelling, and the detail of those particulars that are commonly known.

Though the term enamelling is usually confined to the ornamental glazing of metallic surfaces, it strictly applies to the glazing of POTTERY or porcelain, the difference being only that in the latter the surface is of baked clay. With regard to the composition of coloured enamels (which are all tinged by different metallic oxyds) a very general account of the substances used will suffice in this place, and the rest of the subject may be properly referred to the article of coloured GLASS. The enamelling on metals therefore will only be noticed in this place.

The only metals that are enamelled are gold and copper, and with the latter the opaque enamels are only used. Where the enamel is transparent and coloured, the metal chosen should be of that kind as not only to have its surface unalterable when fully red-hot, but also to be in no degree chemically altered by the close contact of melted glass, containing an abundance of some kind of metallic oxyd. This is the chief reason why coloured enamelling on silver is impracticable, though the brilliance of its surface is not impaired by mere heat, for if (for example) an enamel made yellow with oxyd of lead or antimony is laid on a surface of bright silver, and kept melted on it for a certain time, the silver and the enamel act on each other so powerfully that the colour soon changes from a yellow to an orange, and lastly to a dirty olive. Copper is equally altered by the coloured enamels, so that gold is the only metal which can bear the long contact of the coloured glasses at a full red heat, without being altered by them.

The simplest kind of enamel is that fine white opaque glass which is applied to the dial-plate of watches. The process of laying it on (which may serve as a general example of the art) is the following:

A piece of thin copper sheet hammered of the requisite convexity is first accurately cut out, a hole drilled in the middle for the axis of

the hands, and both the surfaces made perfectly bright with a scratch brush.

A small rim is then made round the circumference with a thin brass band rising a little above the level, and a similar rim round the margin of the central hole. The use of these is to confine the enamel when in fusion, and keep the edges of the plate quite neat and even. The substance of the enamel is a fine white opake glass, the material of which will be presently mentioned. This is bought in lump by the enamellers, and is first broken down with a hammer, then ground to a sufficiently fine powder, with some water in an agate mortar; the superfluous water being then poured off, the pulverized enamel remains of about the consistence of wetted sand, and is spread very evenly over the surface of the copper plate by many dexterous manipulations. On most enamellings, and especially on this it is necessary also to counter enamel the under or concave surface of the copper plate to prevent its being drawn out of its true shape by the unequal shrinking of the metal and enamel on cooling. For this kind of work the counter-enamel is only about half the thickness on the concave as on the convex side. For flat plates the thickness is the same on both sides.

The plate covered with the moist enamel powder is warmed and thoroughly dried, then gently set upon a thin earthen ring that supports it only by touching the outer rim, and put gradually into the red-hot muffle of the enameller's furnace. This furnace is constructed somewhat like the assay furnace, but the upper part alone of the muffle is much heated, and some peculiarities are observed in the construction to enable the artist to govern the fire more accurately.

The precise degree of fire to be given here as in all enamelling, is that at which the particles of the enamel run together into an uniform pasty consistence, and extend themselves evenly over the surface shewing a fine polished face, carefully avoiding on the other hand so great a heat as would endanger the melting of the thin metallic plate. When the enamel is thus seen to *sweat down*, as it were, to an uniform glossy glazing, the piece is gradually withdrawn and cooled, otherwise it would fly by the action of the cold air.

A second coating of enamel is then laid on and fired as before, but this time the finest powder of enamel is taken, or that which remains suspended in the washings. It is then

ready to receive the figures and division marks, which are made of a black enamel, ground in an agate mortar with much labour to a most impalpable powder, worked up on a pallet with oil of lavender, or spike, and laid on with an extremely fine hair brush. The plate is then stoved to evaporate the essential oil, and the figures burnt in as before. The polishing with tripoli and minuter parts of the process need not be here mentioned.

If the enamel be chipped off a dial plate (which may be done with the utmost ease by bending it backwards and forwards, as the adhesion between the metal and glazing is very slight) the part immediately in contact with the copper will be found deeply and nearly uniformly browned, which shews how unfit copper alone would be for the transparent enamels.

The regulation of the fire appears to be the most difficult of all the parts of this nice process, particularly in the fine enamelling of gold for ornamental purposes, of designs, miniatures and the like, where three, four, or sometimes five separate firings are required. If the heat is too low the enamel does not spread and vitrify as it ought; if too high, it may be enough to melt the metal itself, whose fusing point is but a small step above that of the enamel, or else (what is an equal mortification to the artist) the delicate figures, laid on with so much care and judgment, melt down in a moment, and the piece exhibits only a confused assemblage of lines and fragments of designs.

The exact composition of the opake white enamel is a matter of considerable importance, and is procured by the enamellers from persons whose business it is to prepare it. A good enamel of this kind, fit to be applied both to porcelain and metals, should be of a very clear fine white, so nearly opake as only to be translucent at the edges, and at a moderate red heat it should run into that kind of paste, or imperfect fusion which allows it to extend itself freely and uniformly, and to acquire a glossy even surface, without however fully melting into a thin glass. The opake white of this enamel is given by the oxyd of tin, which possesses, even in a small proportion, the property of rendering vitrescent mixtures white and opake, or in still less proportion, milky, and, when otherwise coloured, opalescent. The oxyd of tin is always mixed with three or four times its quantity of oxyd of lead, and it appears necessary that the metals should be previously mixed by melting, and the alloy then calcined.

The following are the directions given by Clouet for the composition of this enamel.^a Mix 100 parts of pure lead with from 20 to 25 of the best tin, and bring them to a low red heat in an open vessel. The mixture then burns nearly as rapidly as charcoal and oxidates very fast. Skim off the crusts of oxyd, successively formed, till the whole is thoroughly calcined. It is better then to mix all the skimmings and again heat as before till no flame arises from them, and the whole is of an uniform grey colour. Take 100 parts of this oxyd, 100 of sand, and 25 or 30 of common salt, and melt the whole in a moderate heat. This gives a greyish mass, often porous and apparently imperfect, but which however runs to a good enamel when afterwards heated. This is the enamel used for porcelain, but for metals and finer works the sand is previously calcined in a very strong heat with a fourth of its weight, or, if a more fusible compound is wanted, as much of the oxyd of tin and lead as of salt is taken, and the whole melted to a white porous mass. This is then employed instead of the rough sand as in the above-mentioned process. The above proportions however are not invariable, for if more fusibility is wanted the dose of oxyd is increased, and that of the sand diminished, the quantity of common salt remaining the same. The sand employed in this process according to M. Clouet is not the common sort however fine, but a micaceous sand, in which the mica forms about one-fourth of the mixture.

Neri in his valuable treatise on glass-making has given long ago the following proportions for the common material of all the opaque enamels, which Kunckel and other practical chemists have confirmed. Calcine 30 parts of lead with 33 of tin, with the precautions mentioned above. Take of this calcined mixed oxyd 50 lb. and as much of powdered flints (prepared by being thrown into water when red-hot, and then ground to powder) and 8 ounces of salt of tartar, melt the mixture in a strong fire kept up for 10 hours, after which reduce the mass to powder. This is the common material for the opaque enamels, and is of a grey white. To make this fine enamel quite white, mix 6 lb. of this material with 48 grains of the best black oxyd of manganese, and melt in a clear fire. When fully fused throw it into cold water, then remelt and cool as before two or three times till the enamel is quite white and fine. Kunckel observes on this process, that he tried it without the oxyd of manganese, but the enamel instead of being milk-white was blueish and not good,

so that there is no doubt but that this oxyd is highly important. If too much is used the enamel becomes of a rose-purple. For further observations on the use of manganese in vitrescent mixtures, see the article GLASS.

Coloured enamels are composed of a common basis, which is a fusible mixture of vitrifiable materials, and of some metallic oxyd. In general the coloured enamels are required to be transparent, in which case the basis is a kind of glass composed of borax, sand, and oxyd of lead, or other vitrescent mixtures, in which the proportion of saline or metallic flux is more or less according to the degree of heat that the colouring oxyd will bear without decomposition. When the coloured enamel is to be opaque or opalescent, a certain portion of the white opaque enamel, or of the oxyd of tin, is added to the mixture. The most beautiful and costly colour known in enamelling is an exquisitely fine rich red with a purplish tinge, given by the salts and oxyds of gold, especially the purple precipitate formed by tin in one form or other, and nitro-muriat of gold, and also by the fulminating gold. This beautiful colour requires much skill in the artist to be fully brought out. It is said that when most perfect it should come from the fire quite colourless, and afterwards receive its colour by the flame of a candle. Gold colours will not bear a violent fire.

Other and commoner reds are given by the oxyd of iron, but this requires the mixture of alumine or some other substance refractory in the fire, otherwise at a full red heat the colour will degenerate into black.

Yellow is given either by the oxyd of silver alone, or by the oxyds of lead and antimony, with similar mixtures to those required for iron. The silver is as tender a colour as gold, and readily injured or lost in a high heat.

Green is given by the oxyd of copper, or it may also be produced by a mixture of blue and yellow colours.

Blue is given by cobalt, and this seems of all enamel colours the most certain, and easily manageable.

Black is produced by a mixture of cobalt and manganese.

Under the article of coloured GLASSES this subject will be noticed more at length.

The reader may conceive how much the difficulties of this nice art are increased when the object is not merely to lay an uniform coloured glazing on a metallic surface, but also to paint that surface with figures and other designs that require extreme delicacy of outline, accuracy of

shading, and selection of colouring. The enamel painter has to work, not with actual colours, but with mixtures which he only knows from experience will produce certain colours after the delicate operation of the fire; and to the common skill of the painter in the arrangement of his pallet and choice of his colours the enameller has to add an infinite quantity of practical knowledge of the chemical operation of one metallic oxyd on another, the fusibility of his materials, and the utmost degree of heat at which they will retain not only the accuracy of the figures which he has given, but the precise shade of colour which he intends to lay on.

Painting in enamel requires a succession of firings; first of the ground which is to receive the design, and which itself requires two firings, and then of the different parts of the design itself. The ground is laid on in the same general way as the common watch-face enamelling already described. The colours are the different metallic oxyds melted with some or other vitrescent mixture and ground to extreme fineness. These are worked up with an essential oil (that of spike is preferred, and next to it oil of lavender) to the proper consistence of oil colours, and are laid on with a very fine hair brush. The essential oil should be very pure, and the use of this rather than any fixed oil is probably that the whole may evaporate compleatly in a moderate heat, and leave no carbonaceous matter in contact with the colour when red-hot, which might affect its degree of oxidation and thence the shade of colour which it is intended to produce.

As the colour of some vitrified metallic oxyds (such as that of gold) will stand only at a very moderate heat, whilst others will bear, and even require, a higher temperature to be properly fixed, it forms a great part of the technical skill of the artist to apply the different colours in proper order; fixing first those shades which are produced by the colours that will endure the highest heat, and finishing with those that demand the least heat. The outline of the design is first traced on the enamel, ground and burnt in; after which the parts are filled up gradually with repeated burnings, to the last and finest touches of the tenderest enamel.

Transparent enamels are scarcely ever laid upon any other metal than gold, on account of the discoloration produced by other metals, as already explained. If however copper is the metal used, it is first covered with a thin enamel coating, over which gold leaf is laid and burnt in, so that in fact it is still this metal that is the basis of the ornamental enamel.

With regard to the vast number of important minutiae in the selection and order of applying the colours, the management of the fire, &c. &c. almost the whole of what is known on this subject is confined to the practical artist, nor could this knowledge, if obtained, interest the general reader.

ENS MARTIS. A name given by the old chemists to sal-ammoniac sublimed with iron filings, and therefore consisting of muriat of ammonia mixed with a little muriat of iron.

ENS VENERIS. A preparation similar to the foregoing, except that copper filings are substituted to those of iron.

EPIDERMIS. See SKIN.

EPIDOT. See STRAHLSTEIN.

EPSOM SALT, See SULPHAT OF MAGNESIA.

ERBSENSTEIN. See LIMESTONE.

ERDOEL. See BITUMEN.

ESSAY. See ASSAY.

ESSENCE. See OIL *Essential*.

ESSENTIAL SALT. This term seems to be generally applied to express any kind of salt procured from organized bodies, particularly vegetables, by simple extraction without any chemical decomposition. It is therefore synonymous with *native salt*. Thus we have the *essential salt* of *sorrel*, which is the native super-oxalat of potash contained in the plant, and procured by expression, clarification, and evaporation, all of them rather mechanical than chemical processes. The supertartrate of potash is an essential salt in tamarinds, the citric acid in lemons, the malic acid in apples, and the like.

The medicinal virtue of plants was thought formerly to reside peculiarly in the essential salt, so that a small dose of the latter would be equivalent to a proportionally large dose of the plant itself, and hence the extraction of the essential salts was an object of more importance to pharmaceutical chemistry than it is at present esteemed.

ETHER. *Ether*, Fr. *Aether*, *Naphte kunstliche*, Germ.

Ether is a light, odorant, inflammable liquid, produced by the action of certain of the acids upon alcohol. Sulphuric ether being the best known we shall commence with this, and pass successively to the rest of the ethers, reserving for the conclusion of the article an examination of the various theories by which chemists have attempted to explain the rationale of this curious and interesting process.

* **SULPHURIC ETHER.**

The mode of preparing sulphuric ether in small quantities is as follows. Take a tubu-

lated glass retort of the capacity of five quarts or more, lengthen its beak by an adapter and pass the other end of the adapter into a two necked quilled balloon receiver; fix another adapter into the opposite neck of the balloon, to which attach a common quilled receiver, placed in such a position that the quill instead of pointing directly downwards as in the first balloon, shall slant gently upwards: then lute all the junctures with linseed meal, except that of the retort to the adapter; adapt also an 18 ounce vial to the quill of the first receiver, and loosely close the quill of the second with a small cork or a plug of wetted paper. The lute being moderately dry and hard, withdraw the retort and pour in through the tubular 32 ounces by weight of rectified alcohol, and a like quantity of concentrated sulphuric acid. This latter, on account of its superior specific gravity, will fall immediately through the other liquid without producing much heat; in a short time however a considerable quantity of heat is extricated and the two fluids are to be gradually mixed by communicating to them a gentle circular motion. When the mixture is complete the retort is to be replaced in its former position, its juncture with the adapter is to be closed with lute, and a pot of lighted charcoal is to be placed beneath it. The first impression of the fire drives over a little highly dephlegmated alcohol, but as soon as the mixture begins to boil, the ether itself passes over and condenses on the sides of the receiver in large streaks: it is now essentially requisite to keep the receiver as cool as possible by the application of wet cloths wrung out in cold water and frequently renewed, and if this is sedulously attended to, by far the greater part of the ether will be condensed in the first receiver, whence it will flow into the vial beneath, a little however will pass through the second adapter into the second receiver, where it must be condensed by the same means as have been already recommended for the first. The contents of the retort are to be kept moderately boiling till sulphureous acid gas begins to pass through the quill of the second receiver, which may be known at once by its strong suffocating odour: as soon as this is perceived the fire is to be withdrawn, and a minute or two after the vial is to be detached from the receiver, and its contents immediately poured into a ground stoppered bottle; being then replaced as before, the process of distillation is to be recommenced till about four ounces more of a coloured liquid are produced, at which time the operation, as far

as the procuring of ether is concerned, is finished. The liquor last procured consists of two distinct fluids in nearly equal proportions, of these the lightest is an impure ether called oil of wine, and the heavier is water mixed with a little ether, acetous and sulphureous acids. The latter may be separated from the former by inverting the vial that contains them, and holding its neck immersed in water while the warm hand is applied to the upper part of the vial: the gentle warmth thus communicated is sufficient to convert a little of the ether into vapour, and in consequence to expel the acidulous liquor. The whole produce according to this mode of proceeding, from 32 ounces of alcohol and the same quantity of sulphuric acid, is 14 ounces of impure ether condensed in the first and second receivers, and 2 ounces of oil of wine. By subsequent rectification in the manner hereafter described, these 16 ounces will afford 11 ounces of a very pure and highly rectified ether. Some chemists by way of saving trouble allow the ether and oil of wine to mix together in the receiver, and draw off exactly the same quantity of impure ether (18 ounces) as in the former method: this however is injudicious, since the quantity of rectified ether which it yields is by no means so great as when the latter and most impure part of the distillation is collected by itself.^a

It appears from the experiments of Dollfus,^b and is confirmed by the practice of those who prepare ether in the large way, that sulphuric acid is capable of converting into ether considerably more than its own weight of alcohol. The experiment of this able chemist to which we particularly refer is the following. Having mixed very slowly and gradually 32 ounces of sulphuric acid, sp. gr. 1.98, with an equal weight of alcohol, he distilled the whole by a very gentle fire. The first ten ounces that came over were dephlegmated alcohol combined with some ether, the anodyne liquor of Hoffman; the next portion amounting to twelve ounces was impure ether; after this were obtained two ounces more of impure ether contaminated by sulphureous acid: the distillation was carried on still further in order to dephlegmate the sulphuric acid, till three ounces of a weak acidulous liquor mixed with a little thick oil were driven over. To the concentrated acid now remaining in the retort were added 24 ounces of alcohol, and the distillation was recommenced as before; the first seven ounces that were collected were anodyne liquor like the former, the next ten

^a Leonhardi's Macquer, art Aether.

^b Pharmaceutisch-chemische erfahrungen.

ounces were impure ether, after which came two ounces more contaminated by sulphureous acid. The residual acid in the retort was again dephlegmated by driving over five ounces of acidulous liquor, and a third dose of alcohol amounting to twenty ounces was added; from this were obtained six ounces of anodyne liquor, 4 ounces of ether, one ounce of sulphureous ether, and four ounces of weak acidulous liquor with a little oil of wine. Lastly, twenty ounces more of alcohol were added and yielded 5 ounces of anodyne liquor, 8 ounces of ether, one ounce of sulphureous ether, and the residue being loaded with charcoal swelled up so much as to render its further concentration impossible. There were thus procured from 32 ounces of sulphuric acid and 96 ounces of alcohol, 28 ounces of anodyne liquor, 34 ounces of impure ether, and 6 ounces still further contaminated by sulphureous acid; the two last products, amounting to 40 ounces, yielded 28 ounces of highly rectified ether. The sulphuric acid remaining in the retort was quite thick and black in consequence of the charcoal deposited from the decomposition of the alcohol, but being filtered through pounded glass and afterwards rectified by distillation, afforded above 19 ounces of colourless sulphuric acid; sp. gr. 1.72.

Having thus ascertained that sulphuric acid was capable of etherizing a much larger proportion than its own weight of alcohol, it became a matter of some consequence to discover whether by adding the whole quantity of alcohol at once, an equal produce of ether could be obtained as when the process was divided into four distinct distillations. For this purpose M. Dollfus mixed at once 32 ounces of sulphuric acid of the same specific gravity as in the former experiment, with 96 ounces of alcohol, and proceeded to distillation. The first twelve ounces were alcohol but little altered, then came 34 ounces of impure ether, which by rectification afforded no more than about 11 ounces of pure ether: the succeeding products were weak acetous acid and sulphureous acid. The residue in the retort, by filtration and concentration yielded 27 ounces of sulphuric acid; sp. gr. 1.66.

From these experiments it appears that the following practical conclusions may be drawn, First, that by means of repeated distillations, one part of sulphuric acid will convert into ether from two to three times its weight of alcohol. Secondly, that the produce is the greatest when the distillation is carried on very

slowly, and no doubt the quantity of ether would be very much increased if the anodyne liquor produced in one distillation was added to the alcohol employed in the succeeding one. Thirdly, that when the sulphuric acid becomes so thickened with the deposited charcoal as to be incapable of being further used, a large proportion of it may be recovered by filtration through coarse sand or pounded glass, and subsequent concentration.

Ether when fresh distilled is contaminated by sulphureous and acetous acids and a little coloured oil; in consequence of which it is necessary to have recourse to rectification in order to purify it. This is generally done by adding to the ether successive portions of caustic potash or soda dissolved in water, and shaking together the two fluids in a well closed bottle after each addition of alkali, till the odour of sulphureous acid is totally destroyed, the contents of the bottle are then to be poured into a retort, and on the application of a very gentle heat, never amounting to ebullition, the ether will pass into the receiver in a state of great purity, leaving behind it a watery saline liquor covered with a thin film of brownish yellow oil. When the ether is wanted for very delicate chemical experiments it may be again agitated with $\frac{1}{20}$ of its weight of alkaline ley, and distilled in a heat not exceeding 100° Fah. the first $\frac{3}{4}$ of the ether, being absolutely pure, is to be saved apart.^c When ether is to be rectified with peculiar care, Scheele^d recommends that the alkali employed for this purpose should be dissolved in alcohol instead of water: the advantage of this is that no spontaneous separation of the liquors takes place, and therefore the sulphureous and acetous acids are neutralized and separated with greater certainty. Distillation at a gentle heat will readily separate the ether from the other ingredients. A cheap and very effectual method of rectifying ether is the following, first employed by Mr. Woulfe: "Fill three-fourths of a bottle with the impure ether, add a little water and a portion of slacked lime. Agitate the bottle with violence, and keep it for some time in water before taking out the cork. If the smell of the sulphureous acid be not removed, add a little more lime and agitate a second time. Decant off the ether into a receiver and distil it over."^e

Another very cheap and ingenious process was invented by Pelletier.^f It consists merely in adding to the impure ether a little finely pulverized black oxyd of manganese: the mixture being

^c Higgins's Minutes, p. 72.

^d Essays, p. 301.

^e Thomson's Chemistry, ii. p. 229.

^f Memoires, i. p. 316.

corked up in a bottle or flask is to be well shaken together four or five times a day for the space of a week, at the end of which time the sulphureous acid, being first converted into the sulphuric by part of the oxygen of the manganese, is found combined with the metallic oxyd into sulphat of manganese, from which the ether may be poured off quite pure without the necessity of re-distillation. M. Dizé's method^g is the same as the above, except that he separates the ether by distillation, which is probably an improvement.

Rectified sulphuric ether exhibits the following properties. It is a transparent colourless liquor, of a peculiar and to most persons an agreeably fragrant odour and a hot penetrating and somewhat suffocating taste. Its specific gravity, according to Lavoisier, is $= 0.758$. It is volatilizable more rapidly and at a lower temperature than any other liquid, a considerable proportion being lost, especially in warm weather, by merely pouring it from one vial into another: hence the vessels in which it is preserved ought to be very accurately closed, and for further security are often kept inverted in cold water. It boils at 98° under the usual atmospherical pressure, and at 20° *in vacuo*.

The elastic force of the vapour of ether whose boiling point at 29.75 bar. is 102° Fahr. has been examined by Mr. Dalton^h with the following results. At 62° its force is equal to the pressure of 12.75 inches of Mercury; at 102° equal to 30 inches; at 147° equal to 64.75 inches; and at 212° equal to 137.67 inches.

Owing to the extraordinary rapidity with which ether evaporates, it possesses a very great power of refrigeration: this is made obvious to the feeling by pouring a little into the palm of the hand; it is almost instantly volatilized, and the hand becomes painfully cold. Another striking experiment to the same purpose is the following. Fasten a little fine tow by means of a thread round the naked bulb of a mercurial thermometer, and suspend it before the nozzle of a double bellows, then pour some ether on the bulb so as to soak the tow thoroughly, and immediately direct upon it a continued stream of air from the bellows, renewing the ether as soon as it is evaporated: by this management at any common temperature of the atmosphere, the mercury in the thermometer will in about a minute be lowered to 0° Fahr. Ether, notwithstanding its ready volatility, is capable of being congealed at a low temperature. If a

small matrafs full of this fluid is cooled down to -25° Fahr. by a mixture of snow and muriat of lime, and kept quiet in these circumstances for a few minutes, the liquor becomes gradually filled with brilliant transparent crystalline laminæ resembling benzoic acid or oxymuriat of potash, and presently, especially at a somewhat lower temperature, the whole is congealed into a white almost inodorous mass.ⁱ Ether is remarkably inflammable, taking fire instantly on the near approach of an ignited body: it burns with a large white flame and a little smoke, and is resolved into water, carbonic acid, and a minute quantity of charcoal. When passed through a red hot earthenware tube it is entirely decomposed, and a large production of carburated hydrogen takes place. Ether remarkably increases the bulk of any of the permanent gases to which it is added, as was first observed by Dr. Priestley.^k A small quantity of this fluid being mixed with oxygen confined over mercury, exactly doubled its bulk, nor could any additional portion occasion a further dilatation; nearly the same effect took place with atmospherical air, azot, hydrogen, nitrous gas, and carbonic acid, but by a slight agitation in water the ether was absorbed and the gas resumed its former dimensions unaltered in any of its properties. If oxygen gas thus dilated by ether is set fire to, it burns rapidly but does not explode, but if one part of this mixture is added to three parts of oxygen, an ignited body or the electric spark then produces a dreadful explosion, the products of which are water and $2\frac{1}{3}$ parts of carbonic acid gas. Hence it appears that one part of ether requires about 7, or more correctly 6.8 of oxygen for its saturation, the products being water with 4.6 carbonic acid, the proportion therefore of carbon to hydrogen in sulphuric ether is nearly as 5 to 1.^l

Water and ether appear to combine with each other in two different proportions: if equal parts of these fluids are shaken together in a graduated tube, the ether will be found to have diminished in bulk about $\frac{1}{10}$, and the water to have enlarged in nearly the same proportion; the lower fluid consists of water saturated with ether, and the upper fluid is ether combined with a little water. The ether in this state is said to be *washed*, and acquires in consequence some properties that pure ether does not possess; in particular it is now capable of dissolving caoutchouc with great ease, whereas this substance is acted on by pure ether only in a very

^g Thomson.

^h Manchester Phil. Transf. v. p. 564.

ⁱ Vauquelin. An. de Chim. xxix. p. 287.

^k Experiments on Air, methodized, ii. p. 436.

^l Cruikshank in Nicholson's Journ. 4to. v. p. 205.

imperfect manner. Phosphorus is soluble in ether, but the solution is not luminous: when ether is boiled on phosphorus, it often deposits crystals by cooling;^m agitation with water produces no apparent change in this liquid, but the addition of a little alcohol occasions an immediate turbidness, whence the sophistication of ether by alcohol may be detected by mixing a few drops of it with phosphorized ether.ⁿ The fixed alkalies seem to be incapable of uniting with ether, but ammoniacal gas is absorbed by it very copiously: the same may be observed of nitrous gas, but neither of these combinations have as yet been submitted to chemical examination. Sulphuric acid acts on ether with considerable energy, especially when assisted by a gentle heat; it is converted into a brownish oily fluid much heavier than ether, called *oil of wine*, and at a higher temperature is changed into olefiant gas. With regard to the action of oxymuriatic acid on ether a curious experiment is related by Mr. Cruikshank. "If we fill a bottle of the capacity of three or four pints with the pure oxygenated muriatic acid gas, taking care to expel the water as completely as possible, and then throw into it about a drachm or half a drachm of good ether, covering its mouth immediately with a piece of light wood or paper; in a few seconds white vapour will be perceived moving circularly in the bottle, this will soon be followed by an explosion accompanied by flame, at the same time a very considerable quantity of carbon will be deposited, and the bottle will be found to contain carbonic acid gas." Nitric acid excites a considerable effervescence with ether, and seems to convert it into oil of wine. The essential oils are soluble in ether, and it combines with alcohol in almost all proportions.

** NITROUS ETHER.

Although Nitrous ether appears to have been known to Basil Valentine and Kunckel, yet the mode of its preparation being kept a secret it soon ceased to be attended to by chemists, till in the year 1740 it was re-discovered by Duhamel, and afterwards more particularly described by Navier, Sebastiani, and others.

It was prepared by Navier in the following manner. Put 12 ounces of rectified alcohol into a strong bottle, and add to it gradually, and at intervals 8 ounces of strong nitric acid: after each portion of acid the liquors are to be well mixed by agitation, and the bottle is to be kept close corked and immersed up to its neck

in ice and water. When the whole of the acid is added, the bottle is to be well corked and further secured by a leather cap. A stratum of ether rises by degrees to the surface of the liquor, and after five or six days the cork is to be pierced by a needle in order to let out the nitrous gas formed during the process: this gas having escaped the cork is to be drawn, and the whole contents of the bottle being poured into a separatory funnel, the ether is thus procured unmixed with the heavier fluid on which it floats. This is however a very rude way of proceeding, and is attended with the utmost risk to the apparatus, the ether obtained is also in small quantity and very impure. A safer and more economical, but somewhat tedious mode of proceeding was invented by Dr. Dehne.^o He luted a tubulated retort to a large receiver, and poured into the retort 32 ounces of alcohol, to which he added every four hours half an ounce of fuming nitrous acid drop by drop. When twelve ounces and a half had been thus poured in, the mixture began to bubble but without much heat, and an ounce of ether came over into the receiver. After this two drachms of the acid only were added morning and evening: on the eighth day after the commencement of the process a stratum of greenish ether appeared on the surface of the liquor in the retort, which being removed on the twelfth day (at which period 21 ounces of acid had been added to the alcohol) was found to amount to 17 ounces. The daily addition of two drachms of acid was still continued till it fell to the bottom in the form of green bubbles, indicating the saturation of the alcohol; at this time eight ounces and three drachms more of ether were separated, amounting in the whole to 26 ounces and 3 drachms; the residuum weighed 28 ounces, and the loss of weight during the entire process amounted to 5 ounces.

In order to prevent the violent and rapid action of the concentrated acid on the alcohol, which is the chief difficulty in the preparation of nitrous ether, Dr. Black proposed to interpose a thin stratum of pure water, and Fischer on the same principle made use of a little weak spirit of nitre for a similar purpose. M. Dollfus from a careful repetition of this latter process obtained the following result. Upon two ounces of strong nitric acid he poured six drachms of the same very much diluted, and upon this three ounces of rectified alcohol. The vial was loosely corked and suffered to stand undisturbed for three days: at this time

^m Mrs. Fulham on Combustion, p. 41.

ⁿ Brugnatelli An. de Chim. xxiv. p. 73.

^o Crell's Chim. Journ. i. 44.

the lower liquor appeared perfectly homogeneous with a stratum of ether floating above it. The whole being put into a retort and subjected to a gentle heat, there was obtained two ounces and a drachm of very pure ether unmixed with any acid, and the residue in the retort consisted of weak acetous acid mixed with oxalic acid, nearly the whole of the nitrous acid having been decomposed.

Another equally eligible method of preparing nitrous ether was invented by Chaptal, and has since in some respects been improved by Proust: It consists in first putting together an apparatus consisting of a tubulated retort and two balloon receivers, each furnished with a tube of safety, and the whole terminated by three Woulfe bottles; 32 ounces of alcohol are then to be poured into the retort, and the Woulfe bottles are likewise to be half filled with alcohol: nitric acid is then to be poured by degrees into the retort till it amounts to 24 ounces; and then the tubulure being closed by its stopper a gentle heat is to be applied: both nitrous gas and ether are rapidly disengaged, the latter of which is in part condensed in the receivers, but principally in the Woulfe bottles where it floats on the surface of the alcohol. Dollfus^p has repeated this process in a simpler apparatus with the following results. Into a tubulated retort containing three ounces of alcohol he dropped one drachm of nitrous acid, repeating this at short intervals till the quantity amounted to two ounces. Then distilling this mixture by a gentle fire he obtained two ounces and a drachm of ether: the residuum weighed two ounces, from which he procured by a second distillation one ounce of a weak acetous acid: from the residue by the addition of a little more nitrous acid, there separated by crystallization one drachm and 15 grains of oxalic acid.

The last mode by which nitrous ether may be prepared that we shall mention, and which on the whole appears to be the best, consists in mixing together alcohol and sulphuric acid, and pouring the liquor upon pulverized nitre; the sulphuric acid disengages the nitrous acid which immediately acts on the alcohol, and ether is the result. The able chemist whom we have already mentioned has shewn the excellence of this mode by the following experiment.^q Having put into retort four ounces of perfectly dry and pulverized nitre, he added to it a mixture consisting of two ounces of concentrated sulphuric acid, and four ounces of alcohol; the whole being submitted to distillation there came

over first six drachms of dulcified spirit of nitre, and then three ounces of a liquor, from which, by subsequent rectification were procured two ounces of pure ether.

Nitrous ether when recently made contains in loose combination a considerable quantity of nitrous gas, which in some degree modifies its properties, and renders it particularly liable to burst the bottles in which it is kept, especially in warm weather; another inconvenience is, that if the bottles are not quite full and closed with perfect exactness, the nitrous gas by the absorption of the oxygenous portion of the air is converted into nitrous acid, and in consequence reacts on and destroys a part of the ether, converting it into water and oxalic acid, which in proportion as they are produced descend to the bottom of the vessel forming an acid liquor on which the rest of the ether floats. This loss and trouble however may be avoided by rectifying the ether, which is done best in the following way. Pour into a strong vial so as to fill it about two-thirds, one part of ether and four parts of pump water, and agitate it cautiously at first, and occasionally removing the thumb from the mouth of the vial to afford a free passage for the disengaged nitrous gas: when no more of this air is extricated, add a quantity of dry pearlash equal in weight to the ether, and shake the whole well together: then transfer the mixture into a tubulated retort and proceed to distillation, taking care that the temperature does not exceed 120° Fah.: the ether will pass into the receiver quite pure, and may be kept for any length of time in strong well closed bottles with no more risk of accidents than sulphuric ether is subject to.

Nitrous ether resembles sulphuric ether in most of its properties, it has however a dilute yellow colour, and a somewhat different odour and flavour; this appears to be owing to a little resinous matter from which it can never be entirely freed: by repeated distillation from fresh parcels of dry white sugar, as Deyeux has observed, this impurity may in great part be separated, and in proportion as this takes place the ether becomes more and more analogous to that prepared by sulphuric acid.

Nitrous ether appears capable of uniting with nitrous gas in two proportions: when the ether is in excess it forms nitrous ether in the state in which it appears previous to rectification; when the nitrous gas exceeds the ether it composes a permanently elastic fluid that has obtained the name of *etherized nitrous gas*. The

^p Erfahrungen, &c.

^q D°.

preparation of this differs from that of nitrous ether only in the rapidity with which the acid and alcohol act on each other: when the combination takes place very slowly much ether and little etherized gas is the result, but when the contrary is the case, these two products are formed in an inverse proportion. If equal parts of alcohol and strong nitrous acid are mixed together at the usual atmospheric temperature, or at a higher heat in proportion as the acid is diluted, a very rapid and copious effervescence takes place, a little ether is condensed in the receiver, and a large quantity of gas passes through the conducting tube, the first portions of which are etherized nitrous gas, and the latter part common nitrous gas. What remains in the retort is acetous acid with a little oxalic acid. The properties of etherized nitrous gas, according to Van Deiman and his associates, to whom we are indebted for its discovery are the following.^{*} It has a disagreeable ethereous odour exactly resembling that of olefiant gas when treated with oxymuriatic acid. By the application of flame it takes fire and burns with a yellowish lambent flame like alcohol: after the combustion has ceased the vessel in which it has been carried on contains a vapour of singular pungency. Water completely absorbs this gas, but requires a considerable time to effect it except agitation is had recourse to, resembling in this respect carbonic acid. Alcohol produces the same effect as water, and takes up the gas not only more rapidly but also in larger proportion. A solution of caustic potash also dissolves it, but with considerable difficulty, and on the addition of sulphuric or muriatic acid the etherized gas is again set at liberty unaltered in any of its properties. Ammonia, whether liquid or in the gaseous state, is incapable of contracting any union with it. The same is the case with oxygen gas at the common temperature, but a mixture of the two airs when inflamed occasions a most violent explosion. Sulphuric acid instantly decomposes this gas by absorbing the ether, the nitrous gas retaining its elastic state. Sulphureous acid produces the same effect, only it requires some days for this purpose. If sulphuric acid previously diluted with an equal weight of water is placed in contact with this gas over mercury, its action is greatly retarded; the diminution of volume in the inclosed air takes place much more slowly, and even after some days a minute portion of etherized gas is retained by the nitrous gas, which in consequence acquires the property of

enlarging the flame of a taper that is immersed in it, in the same manner as nitrous oxyd does. Nitrous acid according to its degree of concentration absorbs either wholly or in part the ethereous portion of the gas; and the same may be observed of muriatic acid.

Etherized nitrous gas when passed through a red hot glass tube deposits a little oil, and by subsequent washing with lime-water is freed from some carbonic acid; the residue is nitrous gas mixed or combined with common carburetted hydrogen, and is not acted on by sulphuric, nitric or muriatic acids, by caustic potash or alcohol. The addition of oxygen gas produces red vapours, the nitrous gas is converted into acid, and the gaseous residue is carburetted hydrogen.

* * * MURIATIC ETHER.

After chemists had shewn the production of ether by means of the sulphuric and nitric acids, it was natural to attempt its preparation by the muriatic acid. But this latter in its usual state of dilution with water has no action on alcohol, and therefore the various modes that were at first practised to produce muriatic ether entirely failed. A few chemists were said to have succeeded by employing simple muriatic acid, but in a more concentrated and dry state than the liquid acid; the process however was both difficult and doubtful, and muriatic ether can hardly be said to have been known till Rouelle discovered that it might be prepared by distilling together alcohol and the smoking liquor of Libavius, which is a concentrated muriat of tin in its highest state of oxydation. The Marquis de Courtanvaux having repeated the experiments of Rouelle with much care, proposes the following as the best method of preparing the substance in question. Mix together in a retort three parts of fuming muriat of tin and one of alcohol, a considerable degree of heat is immediately excited and a white suffocating vapour arises, which however soon disappears on agitating the mixture. As soon as an ethereous odour is perceived, let two balloon receivers be luted on and kept as cool as possible, then by the application of a gentle heat to the retort there comes over first a little dephlegmated alcohol which is succeeded by the ether: by an increase of temperature a few drops of coloured oil are produced, and then arises partly in the form of a soft butter and partly in that of a dense brown liquid, a quantity of smoking muriat of tin, part of the metallic oxyd remaining in the retort as a grey powder. When the

^{*} Jour. de Phys. xlv. p. 245.

ether thus procured is mixed with a solution of pearlsh, a copious effervescence and precipitation takes place, owing to the decomposition of some muriat of tin contained in the ether, after which by distillation at a gentle heat the muriatic ether arises in a state of great purity amounting to half of the impure product of the first distillation.

Several other of the metallic muriats have been found to be equally efficacious with the liquor of Libavius: the corrosive muriats of antimony and arsenic, the muriats of bismuth and zinc, and the red muriat of iron have in particular been used with success in the preparation of muriatic ether.

Scheele, the discoverer of oxymuriatic acid, was induced to try the effect of this in the preparation of muriatic ether.* For this purpose he put three ounces of alcohol into a receiver, with which was connected a retort holding two ounces of common salt, upon which was poured an equal weight of sulphuric acid; the muriatic acid thus disengaged passed into the receiver where it combined with the alcohol, and this when saturated with acid was transferred to another retort containing three ounces of black oxyd of manganese in fine powder: the mixture instantly assumed a green colour and presently after became so hot as to boil. When the ebullition had ceased there was found in the receiver a liquor from which on mixture with water a quantity of ether instantly separated. The same method is recommended by Van Mons, except that he employs only one-fourth of the oxyd of manganese used by Scheele, and performs the second distillation in a Woulfe's apparatus, the bottles of which contain a solution of caustic potash, by which the acid is prevented from reacting on the ether.

Another mode of applying oxymuriatic acid to the preparation of ether, first practised by Scheele, is mentioned by Pelletier,[†] and deserves to be repeated as being perhaps the most expeditious and economical of any. He introduces into a large tubulated retort a mixture of eight ounces of manganese and 16 ounces of decrepitated muriat of soda, upon which he pours another mixture of twelve ounces of sulphuric acid and eight ounces of alcohol. From this mass ten ounces are drawn off by distillation at a gentle heat, which by subsequent rectification yields four ounces of ether.

It deserves to be remarked that the ether prepared by oxymuriatic acid generally deposits

during its rectification with potash a considerable quantity of a clear aromatic and bitter oil, which sinks in drops to the bottom of the vessel: the ether also, according to Dollfus, at least before rectification, is compleatly miscible with water when shaken with it for some time.

The preparation of ether by means of simple muriatic acid is not easy, and was readily supposed to be impossible by some of the leaders of the modern school of French chemists, because it contradicted one of their early theories on the process of etherification; yet Beaumé, a chemist of great experience and unquestioned veracity, had affirmed that he had obtained a small quantity of ether by mixing together alcohol and muriatic acid both of them in the state of vapour: La Planche also had obtained ether by adding to decrepitated muriat of soda a mixture of alcohol and sulphuric acid, and distilling the whole by a gentle heat. A chemist of the name of Martin also affirms that he had prepared muriatic ether by cohobating equal parts of alcohol and muriatic acid, by which process the quantity of ether obtained amounted to half of the alcohol employed. Finally the practicability of this method appears to be established beyond doubt by the following formula of Mr. Basse.[‡] Keep a quantity of common salt in fusion for about an hour in order to drive off all the water of crystallization, then pulverize it, and put 40 parts into a tubulated retort connected with a Woulfe's apparatus, the first bottle of which contains 20 parts of most highly rectified alcohol: then add to the salt in the retort 20 parts of the strongest sulphuric acid, and proceed to distillation by a gentle heat, keeping the alcohol-bottle as cool as possible. When the alcohol is saturated with acid, transfer it to a retort and distil over about one half of it; agitate this portion with an alkaline ley and the ether will presently separate and float on the surface, whence it may be obtained by decantation or distillation. The quantity of ether from the above materials amounts to 5 parts.

Muriatic ether has a striking resemblance to that prepared by sulphuric acid; its specific gravity however is greater, amounting according to Hermstadt to 0.84: its taste also has a peculiar astringency like alum, and when burning it exhales a strong acrid odour resembling that of sulphureous acid.

* * * FLUORIC ETHER.

All that we know of this substance is due to Scheele.[§] He first impregnated rectified alcohol

* Scheele's Essays, p. 302.

† Van Mons Journ. de Chim. iv. p. 86. or Thomson's Chim. ii. p. 246.

‡ Memoires, i. p. 141.

§ Ess. p. 305.

with fluoric acid gas, by distilling pulverized fluor spar with sulphuric acid and placing alcohol in the receiver: the smoking spirit thus obtained was distilled with a gentle heat, but no sign of ether made its appearance. Another portion of the acidulated spirit was then mixed with black oxyd of manganese, and by subsequent distillation an ethereous fluid came over, from which by rectification a little ether was obtained, of a very agreeable smell resembling that of nitrous ether.

*** ACETIC ETHER.

Acetic ether was first discovered by the Count de Lauraguais; the method of its preparation was by distilling together equal parts of alcohol and acetic acid. Scheele, Bergman, Pörner, and other chemists repeated this process ineffectually, and hence were induced to suspect some error. In consequence of these doubts, Pelletier* entered into a careful examination of the subject, and has both shown the reason of the failure of Scheele, and has given the proper method by which to succeed. He distilled together equal parts of alcohol and acetic acid, and drew off a little more than half; this liquor was acidulous and had an ethereous smell, but no genuine ether could be made to separate. He then mixed together 12 ounces of strong radical vinegar and the same quantity of alcohol, and distilled over one half of it at a boiling temperature; this product he poured back into the retort and recommenced the distillation; the produce of this and of the third distillation were in like manner recohobated, and having begun again for the fourth time he finally obtained 12 ounces of an ethereous fluid; with this he mixed a sufficient quantity of carbonated potash to saturate the acid which it contained, and then submitted it to a gentle distillation. The first six ounces that came over were pure acetous ether, the next four ounces also contained ether, but not so pure as the former. It is remarkable that during the cohobations a considerable absorption of air took place.

Scheele obtained acetous ether in a more compendious manner by mixing together acetite of potash, or of lead (sugar of lead), or of copper (distilled verdigris), with alcohol, and then adding as much sulphuric acid as was requisite to decompose the acetous salt and distilling the mixture at a low heat; the produce being shaken with water the ether rises to the surface and may be poured off. From 16 parts sugar of lead, 6 parts strong sulphuric acid, and 9 parts

of alcohol, Bucholz obtained 6 parts rectified ether.

Acetic ether always retains the odour of the acid by which it is formed: it is not so volatile as the ethers procured by the mineral acids; it burns with a lambent blue flame like alcohol; it is soluble in a little more than twice its bulk of water, and is decomposable into acetous acid by repeated distillations at a very gentle heat.

Various other acids have been distilled with alcohol for the purpose of procuring ether, but with little or no success. Oxalic acid with an equal weight of alcohol yielded Bergman a watery somewhat etherized alcohol. Benzoic acid and alcohol, according to Scheele, afford no ether, but when a little common muriatic acid is added to the mixture, an ethereous liquor comes over, of which part floats on water and part sinks in the same fluid. The ether, or the lighter portion, has the odour of benzoic acid, burns with a clear flame and smokes, and is about equal in volatility to acetic ether. The phosphoric, boracic, tartareous, citric, and succinic acids were found by the same able chemist to be incapable of producing ether either by their own action or alcohol, or when mixed with oxyd of manganese or muriatic acid.

*** THEORY OF ETHERIFICATION.

Of the various theories by which chemists have endeavoured to explain the rationale of the curious and interesting process of etherification, we shall mention only three. The first of these, remarkable for its ingenuity and simplicity and the striking similarity which it bears to the theory of Vauquelin and Fourcroy in its leading principle, was invented by Macquer previous to the great changes introduced into the science by the discoveries of Priestley and the other fathers of gaseous chemistry.

Spirit of wine, says Macquer,* which is at once inflammable and miscible with water in all proportions, differs from any oil by containing a more considerable quantity of water, which enters into its composition as a principal or constituent part; hence if we deprive spirit of wine of that aqueous principle by which it differs from oils, it ought to approach so much the more to an oily nature in proportion as it is deprived of the water with which it is combined. Now this is precisely what happens in the process of etherification. When equal quantities of alcohol and sulphuric acid are distilled together, the first produce is alcohol highly dephlegmated; then succeeds ether, which from

* Memoires, i. p. 238.

* Chem. Dict. art. Ether.

its burning with a white flame and smoak, and being immiscible with water in all proportions, approaches nearer to the character of oil than alcohol does. When the alcohol has lost an additional quantity of water it is converted into oil of wine, which is a genuine oil, being not miscible with water, burning with a smoaky flame and leaving behind a resinous coal. In further confirmation of this it may be observed that water is actually separated from the alcohol during the whole of the distillation. The objections to this representation of the process independently of any theory are, that it notices and accounts for only a few of the changes that take place, and therefore is at best imperfect: in particular the copious deposition of charcoal and the formation of acetous acid is wholly neglected.

When the theory and general deductions of Lavoisier began to be received among chemists, and oxygen was considered as the active principle by which all chemical changes were brought about, the formation of ether was very compendiously explained in the following manner. The disengagement of sulphureous acid accompanies the production of ether, therefore "in this operation the sulphuric acid is decomposed, and its oxygen, by combining with the hydrogen and carbon of the alcohol forms three states, which we also find in the distillation of some bitumens; 1. a very volatile oil or ether; 2. ethereal oil; 3. bitumen." Impressed with this idea the same chemist is led to the unfounded assertion that in all the modes of preparing muriatic ether, the acid is in the state of oxymuriatic acid. "It is evident therefore," adds he, "that ether is merely a combination of alcohol with the oxygen of the acids made use of;" and then in order to confirm this position he says that ether may be obtained by repeated distillations of alcohol from the red oxyd of mercury; an assertion which most assuredly is false, except the mercurial oxyd was prepared by nitrous acid, and in consequence of being insufficiently heated contained a portion of it undecomposed; in which case it might perhaps form with alcohol a nitrous ether.

The last theory which we shall mention is that of Vauquelin and Fourcroy: it is the most recent and, because it is founded on a minute attention to the several phenomena that take place during the formation of ether, the most satisfactory of any that have yet been offered. The facts and observations by which this theory is supported are the following. *

1. If one part of alcohol and two of sulphuric acid are mixed together, the temperature rises to about 200° Fah. the mass immediately acquires a deep brownish-red colour, which deepens into black a few days after, and at the same time exhales a vapour manifestly ethereal.

2. Equal parts of concentrated sulphuric acid and rectified alcohol, acquire on mixture a temperature of 190° Fah.; bubbles of gas are extricated, the liquor becomes turbid and opalescent, and at the end of a few days acquires a deep red colour. The whole being then transferred to a distillatory-pneumatic apparatus, and being heated to 207° Fah. ebullition takes place and ether passes over into the recipient: if the operation is carefully conducted, no elastic fluid is disengaged, and the vapour when condensed is found to be only water and ether. When the liquid thus obtained amounts to about half of the alcohol employed, sulphureous acid begins to be manifest, and in a short time the production of ether ceases and is succeeded by oil of wine accompanied by water and acetous acid. The contents of the retort being kept boiling and becoming more and more concentrated as the distillation proceeds, are constantly acquiring a higher temperature: when this amounts to about 234° Fahr. olefiant gas begins to come over and continues till the oil of wine ceases to flow. At this period carbonic acid gas first makes its appearance, the water and sulphureous acid gas still continuing to be produced, and the residue in the retort consists of little else than sulphuric acid thickened by charcoal. A longer continuance of the heat still gradually increasing produces a little water, which soon ceases, sulphureous acid, and carbonic acid, the last of which continues the longest: when no more gas is discharged, the residue in the retort consists of sulphur and charcoal.

These are the facts, and from these the able chemists who observed them have concluded:

1. That the spontaneous action of alcohol and sulphuric acid, when this last is considerably in excess, is sufficient for the formation of ether without the assistance of any extraneous heat, and that by duly proportioning the two substances the alcohol might be wholly decomposed and made to yield all the ether which it is capable of doing when treated in the usual manner.

2. That the formation of ether is not owing to the affinity of the oxygen contained in the sulphuric acid for the hydrogen or carbon of the alcohol, is manifest from the fact that in

* Chapral's Elements of Chim. iii. p. 259.

* An. de Chim. xxiii. p. 203.

the preparation of ether no sulphureous acid gas is evolved till the production of ether has almost ceased. It must therefore be the entire attraction of the sulphuric acid for one or more of the elements of the alcohol that determines its decomposition; now since water is formed during the whole process, and since the affinity of this for sulphuric acid is known to be very powerful, it appears likely that this is the cause that destroys the equilibrium of the affinities by which the elementary particles of alcohol are retained in combination, and induces the oxygen and hydrogen to unite and produce water. Hence it might at first sight be supposed that ether differs from alcohol in containing a smaller proportion of oxygen and hydrogen. This however will not be found to be the case when we advert to the deposition of charcoal, which equally with the formation of water, accompanies the production of ether: now the amount of the charcoal deposited, is greater, in proportion to that which is left, than the hydrogen of the water compared to what still remains in the ether, therefore this latter fluid although composed of the same elements as alcohol, differs from it in containing a smaller proportion of carbon compared to the hydrogen. During the progress of distillation the heat to which the materials in the retort are exposed is continually increasing, and, the affinity of the acid and alcohol also augmenting, the acid itself is at length decomposed: sulphureous acid is generated, and the excess of oxygen deprives the alcohol of part of its hydrogen, whence results the oil of wine, differing from ether in containing a larger portion of carbon; and in confirmation of this it may be observed, that the carbon deposited during the production of oil of wine is not so great as when ether is produced.

The authors of this hypothesis having shown that during the formation of ether no decomposition of the sulphuric acid takes place, attribute to the acid only the power of detaining the alcohol in a heat more than sufficient for the volatilization of this fluid when uncombined, and suppose that the production of ether and water and the deposition of charcoal are to be wholly attributed to the action of caloric. Therefore say they, an analogous decomposition of alcohol takes place in circumstances resembling in no respect those in which sulphuric ether is produced, except the exposure of alcohol to an unusually high temperature. Thus when perfectly caustic potash is mixed with dephlegmated alcohol and heat is gradually applied, the liquor becomes brown by the deposition of

charcoal, water is produced, and an odorant fluid passes over similar in many respects to ether or oil of wine. So again, when the vapour of alcohol is passed through an earthenware tube almost red hot, a decomposition takes place, the products of which are similar to those which appear in the formation of sulphuric ether, except so far as these latter are modified by the decomposition of sulphuric acid. Charcoal is deposited within the tube, a fragrant odour like that of ether is perceived, an oil which concretes into brilliant crystals like benzoic acid is produced, together with olefiant gas, carburetted hydrogen, and carbonic acid.

Such is the substance of this very ingenious theory, and such are the facts by which it is supported; upon which we shall make a few remarks.

In the first place it would have been more satisfactory if the gas had been examined, which we are told is disengaged when equal parts of alcohol and sulphuric acid are mixed together. Secondly, the acetous acid which is copiously formed as long as the oil of wine continues to flow is entirely neglected. Thirdly, the relative proportions of charcoal in alcohol and ether are contradictory to some apparently correct analyses of these substances by chemists of acknowledged ability. Lavoisier from the result of his experiments on fermentation, makes the relative proportions of hydrogen and carbon in alcohol to be as 1 to 1.7: but the process of fermentation is so complicated, that no great dependence can be placed on this result. Let us therefore have recourse to a simpler, and on that account more satisfactory analysis of the same fluid by the same chemist. From the combustion of alcohol in oxygen gas, Lavoisier found the proportions of hydrogen and carbon to be : 1 : 3.6. In ether the proportions of hydrogen and carbon according to Cruikshank, are : 1 : 5. Oil of wine has not been analysed; but in olefiant gas according to Henry, the hydrogen and carbon are : 1 : 5.7 at least, and probably the carbon is in a considerably higher ratio. Now, since during the decomposition of alcohol when distilled with sulphuric acid, ether, oil of wine, and olefiant gas make their appearance in succession; since water is produced during the whole process, and since the deposition of charcoal also takes place but in a diminishing ratio, it appears probable that these different substances form part of a regular series, of which alcohol is one extremity, and olefiant gas the other, and in which the proportion of carbon is constantly increasing, and that of the hydrogen and oxy-

gen diminishing; but as these two last are separated in consequence of the production of water, and perhaps of acetous acid, the oxygen must be abstracted in much greater proportion than the hydrogen, so that the ultimate result of this method of decomposition will be carburated-hydrogen, the oxygen being entirely expended.

Perhaps the following modifications of the theory of Vauquelin may in some degree add to its consistency. Alcohol and sulphuric acid in equal proportions being exposed to a constantly increasing temperature, the acid separates the water contained in the alcohol, and in consequence highly dephlegmated alcohol is the earliest product of the distillation: a greater degree of heat, added to the affinity of the acid for water, decomposes part of the alcohol; its oxygen and hydrogen produce water, and carbon is deposited; but these its elements being separated in unequal proportions ether is the result. At a somewhat higher temperature, before the ether has ceased to flow, the carbon and hydrogen as they are separating from the alcohol react on the sulphuric acid, take away a portion of its oxygen and form acetous acid, while sulphureous acid gas is volatilized together with the last portions of ether. A still greater heat takes away from the alcohol a larger proportion of its oxygen and hydrogen, and oil of wine is the consequence; which probably differs from ether, in containing more carbon and less oxygen; the production of water, acetous acid, and sulphureous acid proceeding as before. The temperature still going on to increase, the oil of wine is itself partly decomposed, and olefiant gas is thus added to the products of the distillation. The oil of wine, olefiant gas and acetous acid at length cease, and nothing comes over but a little water, sulphureous acid and carbonic acid, these last being no doubt produced by the action of the charcoal on the sulphuric acid.

Hence the whole process of etherification, comprehending the conversion of alcohol into ether, oil of wine and olefiant gas may be considered as the effect of a constantly increasing temperature, the action of which the alcohol is prevented from escaping in consequence of its affinity for the sulphuric acid (and as a further proof of this affinity it may be remarked that the most accurately rectified ether always contains a notable quantity of sulphuric acid) The decomposition of this acid and consequent production of sulphureous acid gas has no-

thing to do with the process of etherification; it being caused in the first part of the operation by the formation of acetous acid, and in the latter part of it by the formation of carbonic acid.

It will now be proper to take notice of some objections that have been urged against the theory of Vauquelin and Fourcroy, founded upon experiments in which oxyd of manganese was employed, together with the usual materials of sulphuric ether, and which are supposed by many to demonstrate the necessity of oxygen in the conversion of alcohol into ether.

It was Scheele who first remarked, that if black oxyd of manganese be mixed with sulphuric acid and alcohol, and the whole subjected to distillation, ether is produced without any sulphureous acid making its appearance. This experiment was repeated by Dabit^z with success, and is urged by him to show the necessary agency of oxygen in the formation of sulphuric ether. The acid and the manganese immediately react on each other, says he, sulphat of manganese is the result, and oxygen is disengaged; but no oxygen gas is produced during the whole of the distillation, therefore the oxygen must combine with the alcohol to form ether. Further, there is no deposition of charcoal in the retort, therefore none of the alcohol is destroyed as in the common mode of proceeding. Vauquelin however has positively shown, that in the distillation of sulphuric acid and alcohol the greatest part of the ether passes over before any sulphureous acid is produced; and in reply to this M. Dabit has only to urge the unproved assertion that sulphuric acid may lose a part of its oxygen without becoming sulphureous acid. These objections induced M. Vauquelin to repeat with care the experiments of Dabit, the result of which was a complete refutation of his theory.

* Equal parts of sulphuric acid, alcohol, and oxyd of manganese were mixed together and immediately subjected to distillation: a liquor was obtained amounting to about half of the alcohol employed, which had somewhat of an ethereous odour, but was of a bitter and very disagreeable flavour, was entirely miscible with water, and was specifically heavier than the alcohol made use of, this latter being = 0.83, and the former = 0.86. This liquor being redistilled with carbonated alkali, and $\frac{2}{3}$ of it being drawn off, was found to have acquired a more ethereous odour, its specific gravity was = 0.82; when mingled with an equal bulk of water, be-

^z An. de Chim. xxxiv. 294.

* D^e p. 320

tween $\frac{1}{3}$ and $\frac{1}{4}$ of it remained undissolved in this fluid, and this undissolved part was extremely analogous to common sulphuric ether. On examining the residue of the first distillation a quantity of charcoal was found deposited, and this being contrary to what M. Dabit had affirmed, it was suspected by M. Vauquelin that in consequence of proceeding to distillation immediately after the mixture of the materials, part of the sulphuric acid instead of combining with the oxyd of manganese had acted immediately on the alcohol, and thus had caused the deposition of charcoal and had generated a little real ether. In consequence of this suspicion a second mixture was made of equal parts of sulphuric acid, manganese and alcohol, and was allowed to stand 48 hours before it was distilled. The product of the distillation was a liquid equal to $\frac{6}{10}$ of the alcohol, the odour and nauseous flavour of which were very different from ether. Being rectified in the usual way, somewhat more than half of the liquor was drawn off, which exhibited the following properties. Its specific gravity was ≈ 0.85 , greater than that of the alcohol; it was miscible with water in all proportions; it was less volatile than ether, and its flame though white and accompanied by smoke considerably resembled that of alcohol. On examination of the residue of the first distillation no charcoal was found to be deposited, and this ether when analysed by passing through a red hot earthenware tube, appeared to contain a larger proportion of oxygen and carbon than true sulphuric ether. The facts therefore which have been urged by M. Dabit against the theory of Vauquelin, are in reality a striking confirmation of it, and are particularly interesting as demonstrating the existence of an intermediate substance between alcohol and ether.

The phenomena that take place during the formation of nitrous ether are too complicated, and have been too little observed with the requisite attention to allow us to lay down a satisfactory theory on the subject: not only the alcohol but even the acid is decomposed from the very moment of their mixture; nitrous gas is extricated, and therefore part of the oxygen of the acid is combined with the alcohol; it must be observed however that no charcoal is deposited, and that oxalic and acetic acids are formed besides water and ether; it is very possible therefore that here, as in sulphuric ether, the water and ether are produced by a new arrangement of the elements of the alcohol, and

all the oxygen contributed by the acid is employed in the production of the oxalic and acetic acids.

Where ether is made from the action of muriatic acid on alcohol, it is obvious, as the acid is not decomposed in any part of the process, that this is not in any degree brought about by the action of oxygen. Even when the concentrated metallic muriats are used instead of the simple acid, it may be questioned whether the whole effect is not to be attributed to the concentration of the acid and the remarkable affinity which these salts have for water. The acid in these salts is certainly not in the state of oxymuriatic acid, and it appears from Proust^b that when the smoking muriat of tin is made use of for this purpose, the metallic oxyd is in precisely the same state of oxydation after as before it has been employed in the preparation of ether. The only fact in opposition to this is noticed by Scheele, namely, that the green muriat of iron is incapable of converting alcohol into muriatic ether, whereas the red muriat will effect this change with great ease. He has however omitted to mention whether the red muriat is found after the process in the state of green muriat, which would be the case if the former salt acted in consequence of its excess of oxygen. Muriatic acid, alcohol, and oxyd of manganese however will produce ether, and the oxymuriatic acid is at the same time converted into simple muriatic acid: but according to Mr. Basse,^c the liquid thus produced is not an ether but very similar to the ethereal liquor of M. Dabit mentioned above, and if this is a correct representation, this objection also falls to the ground.

It is an enquiry which has been agitated among chemists whether all the ethers are essentially and radically the same; and it may be supposed that if the theory of etherification is the same in all, the product resulting from this identity of action should also be the same whatever acid is made use of: but in opposition to this it may be stated on the authority of Scheele, that every ether combines with and retains, even after rectification with alkali, a portion of the acid, by the agency of which it was formed, and therefore that there is a real specific difference between ethers depending on the particular acid which enters into their composition.

ETHIOPS.

This term is at present obsolete: it was used by the old chemists to denote four different

^b An. de Chim. xlii. p. 271.

^c Journ. de Chim. iv. p. 88.

metallic preparations of a dark colour, which were for the most part employed in pharmacy.

I. ETHIOPS ANTIMONIALIS.

This is a double sulphuret of antimony and mercury, and is prepared either by triturating equal weights of crude antimony and mercury, till the mercury is no longer fluid; or by fusing some sulphuret of antimony in an earthen crucible, and when it is upon the point of fixing, to pour in an equal weight of hot mercury; the mixture immediately becomes fluid, and after a while solidifies: when cold it must be levigated in a mortar and washed. Instead of crude antimony the golden sulphur of this metal is sometimes made use of.

ETHIOPS MARTIALIS.

This is the pure black magnetic oxyd of IRON; which see.

ETHIOPS MERCURII *per se*.

By this name the older German pharmacopœias distinguish an imperfect oxyd of MERCURY, made by triturating this metal with gum arabic or any other simple mucilage: it is an extremely inartificial and imperfect preparation, the mercury being for the most part not oxydated, but only reduced to a state of very minute division.

ETHIOPS MINERALIS.

This is the artificial black sulphuret of MERCURY; which see.

EUCLASE. *Hauy*.

The colour of this mineral is a very clear sea-green. It occurs only crystallized. Its primitive form is that of an oblique quadrilateral prism, but its summits are generally so complicated by truncatures and bevillings as to render a mere verbal description of it entirely unintelligible: in this state it resembles certain varieties of Topaz, but may readily be distinguished by the measurement of the obtuse angles of the prism being 133° instead of 124° , and in its lamellæ not being perpendicular to the axis of the crystal. It has a brilliant vitreous lustre. Its fracture in the direction of its axis, and parallel to the small diagonal of its base, is perfectly lamellar, but when parallel to the large diagonal is very imperfectly so. Its cross fracture is somewhat conchoidal. It is transparent and has a double refraction. It is sufficiently hard to scratch quartz, but is remarkably brittle. Sp. gr. = 3.06.

When exposed to the blowpipe this mineral first loses its transparency, and then melts into a white enamel. It has been analysed by Vauquelin, with the following result.

Silex . . .	35 to 36
Alumine . .	18 — 19
Glycine . .	14 — 15
Iron . . .	2 — 3
	69 — 73
Loss . . .	31 — 27
	100 100

This mineral is so very rare that only a small portion could be afforded for analysis: of the loss, Vauquelin attributes the greatest part to water of crystallization, and the rest is probably alkali.

The Euclase was found in Peru by Dombey, and all the specimens in the cabinets of Europe were brought over by this naturalist.

EUDIOMETRY.

The term eudiometry is applied to those processes that have been employed to ascertain the purity, or in other words the degree of oxygenation of any gaseous mixture, and especially of atmospherical air.

The relative fitness of air for the purpose of respiration and combustion is certainly a question of high importance, and it has been an object of great moment to determine how far the circumstances of climate, exposure, prevailing wind, and all other meteoric phenomena, crowded population, perceptible fumes or supposed noxious vapours of different kinds, and other causes that affect the sensible quality of the atmosphere, really alter its chemical composition. Besides the varieties in the natural atmosphere, chemists also are constantly producing different gaseous mixtures, the analysis of which is desired; and as far as relates to the quantity of oxygen contained, eudiometry here also may be put into practice: but by far the greater number of eudiometrical observations and experiments that have been made relate to the constitution of the atmosphere alone under different circumstances.

The precise constitution of *atmospherical air* is described under that article; it may be considered as a chemical mixture of azotic and oxygen gases (the small portion of carbonic acid being set aside) in the average proportions of 78 of the first and 22 of the second, estimating by bulk, or of 74 to 26 by weight.

All the eudiometric processes have only for their object to ascertain directly the quantity of oxygen, and the only methods commonly employed are the oxygenation of nitrous gas, of a hydro sulphuret, of hydrogen, and of phosphorus, each of which require a separate con-

sideration. The subject of eudiometry, being one in which much accuracy is required, was long surrounded with difficulties; very complicated chemical decompositions have been discovered in processes that at first were considered only as instances of simple oxygenation; all the scrupulous minuteness in manipulation, and in estimating the real quantities of gaseous bodies has been found essential to procuring just and accurate results; and hence it has happened that none of the discoverers of these processes have been the persons to bring them to perfection. We shall therefore in this place only enlarge upon the latter experiments. The concurring testimony of all the accurate eudiometers shews so great, and to most philosophers unexpected, a similarity in the constitution of the atmosphere in almost every situation in which man can be placed, and in every change of climate or weather, that when we find such enormous differences in the degree of oxygenation of the atmosphere as some observers have given, we may fairly doubt the fidelity of the experiments, or the competency of the method employed. In general therefore we can find no surer test of the accuracy of any eudiometrical process than that, with the same manipulations it will always shew nearly the same quantity in the atmosphere at all times and seasons, that is, within the limits of about one per cent. over or under an average. Instead of this we find on the average of the results of different experimenters a range of sometimes 8 or 10 per cent. in the statements of the quantities of oxygen, even where the same eudiometric substance has been employed; a circumstance which shews the necessity of uniformity not only in the general mode, but even in very minute particulars in order to give comparable results between the observations of different chemists.

Of nitrous gas as an eudiometer.

This was the first eudiometer employed, being used by Dr. Priestley in his original experiments immediately connected with his great discovery of oxygen gas. If nitrous gas be mixed in a glass jar over water with oxygen (both supposed to be perfectly pure and in the proportions in which they mutually saturate each other to form nitric acid) there will be a total disappearance of both gases, the water will be seen to rise and fill the jar, entirely absorbing the newly formed nitric acid in its passage. Though this total absorption of the two gases never actually takes place, yet when they are as pure as possible, and in accurate proportions, it is so nearly complete that the residue amounts

only to a very minute quantity, and is found by experiments to be azotic gas. On the other hand, when nitrous gas is added to *atmospheric air*, or any other mixture of azot and oxygen, a certain and considerable absorption takes place and in direct proportion to the quantity of oxygen present, so that, supposing a constant uniformity of action to be exerted, nitrous gas would possess all the requisites for a perfect eudiometer. Thus, for example, if one measure of pure nitrous gas be added to the same quantity of common air, after a complete mixture of the two has been effected, the air will only occupy the space, on an average, of about 1.08 instead of 2. and consequently .92 parts will have been absorbed. This result Dr. Priestley was in the habit of denoting by the expression, that the air was of the purity of 1.08, equal parts of the two gases being always used. This proportion of nitrous gas is indeed more than sufficient to saturate the oxygen of the atmospherical air, but as no error can arise from an excess of nitrous gas equal to that of having a deficiency of it, these proportions are generally used for all airs supposed to contain not much more oxygen than the atmosphere. For giving *comparative* results of the oxygenation of airs, therefore, no further calculations would be requisite, could the purity of the nitrous gas be ensured. But as the expression, an air of the purity of 1.08, only implies that 1.08 is the unabsorbed residue when 1. of nitrous gas is mixed with 1. of common air, or in other words, an absorption of .92 parts, the actual quantity of oxygen contained in the air must be sought for by other data, which shall determine the relative proportions in which nitrous air and oxygen must be combined to produce a total absorption, and form nitrous acid. Thus if it is found that 3 parts of nitrous gas are required fully to saturate and convert into nitrous acid 1 part of oxygen gas, the .92 parts absorbed in the former instance will have been produced by the union of .69 of nitrous gas and .23 of oxygen; and as all the oxygen is removed from the air by this treatment (there being much more than sufficient nitrous gas for the purpose) we may thence infer that 100 parts of the atmospherical air examined contains 23 of oxygen.

The eudiometer by nitrous gas therefore requires, for actual results, the support of another essential experiment, in which respect the chance of error is greater than if the oxygen was removed by a solid or a liquid put in contact with the air to be examined, and where all

the residue might be simply that of the unabsorbed portion of this air alone. This difference however in the mode of estimation would be of no importance could the action of nitrous gas be brought to be uniform under all circumstances, and divested of many anomalies and uncertainties that now attend its use. The chief of these are the following:

By the very ingenious and accurate experiments of Fontana, Ingenhouz, and Cavendish, it has been fully shewn that different portions of the very same gasses will undergo an enormous difference of absorption according to the width of the tube in which they are mixed, the time of standing together, the mode of shaking, and other smaller manipulations. Thus, as Mr. Cavendish has observed^c, if 1 measure of nitrous gas, and as much common air be rapidly mixed and immediately shaken, the absorption will be nearly half the mixture, but if the airs are suffered to remain in contact about a fourth of a minute before they are shaken, the absorption will be no more than about .8. The nature of the water too in which the experiment is made is found most materially to influence the result. These differences might however be avoided, and the experiments made in this way might be universally comparable if chemists would agree to adopt the same precise method of operating in all the minute particulars that are found to affect their accuracy.

Thus Mr. Cavendish, by observing these precautions, was enabled to ascertain the very great uniformity of the composition of common air in different seasons and situations.

The actual quantity of oxygen contained in the air examined is found (as above-mentioned) by the known composition of nitric acid; there is however another method, which is the removal of unsaturated nitrous gas from the residue which contains only this gas and azot, and thus leaving the azot belonging to the air examined. For this purpose however it is essential to enter into a minute investigation of the nature of the nitrous gas employed, and to ascertain what are its impurities, and whether it can contain any azot, which, by mixing with the azot of the common air, might occasion an error in the inference drawn from the quantity of unabsorbed residue.

The very elaborate series of experiments on this subject undertaken by Humboldt^f first, and afterwards by this chemist and Vauquelin^g, require some attention in this place, though all the observations contained therein have not been

confirmed by other enquirers, and though some of the calculations are founded on hypothetical data, and imply a minuteness of investigation on which the known uncertainty of these experiments will not allow us to place implicit confidence.

According to the above-mentioned chemists, when nitric acid of any strength is added to copper wire (which is the usual method of procuring nitrous gas) an effervescence more or less vehement takes place, and a gas is disengaged consisting of nitrous gas, but always mixed with a portion of azot. The quantity of the latter is found to vary extremely according to the strength of the acid, being from about one-tenth to nearly half the entire gas. Hence the necessity of finding that degree of strength of the acid which will produce the purest nitrous gas: and this degree Mr. Humboldt states to be, that in which the specific gravity is about 1.15 to 1.17, or from 17 to 21 of Beaume's areometer. An acid either stronger or weaker than this gives a much more impure gas.

The mixture of azot with the nitrous gas the above chemists ascertain in two ways, by sulphat of iron and by oxymuriatic gas. Dr. Priestley had found^h that when nitrous gas was agitated with a solution of sulphat of iron, a large portion of the gas was absorbed and the solution became thereby of a dark reddish black colour, and acquired an acid taste, whilst the unabsorbed residue was pure phlogisticated (azotic) air, or nearly so, as one measure of it with as much of fresh nitrous air occupied the space of 1.92 measures. Hence if the residue be the azot preexisting in the nitrous gas, and not formed by the action of the sulphat of iron, this appears a simple and ready way of ascertaining the purity of the nitrous gas, and removing it from the azot left in these eudiometrical experiments.

The precise nature of this mutual action of nitrous gas and sulphat of iron was examined by Messrs. Humboldt and Vauquelin in the following way: to a solution of 1½ ounce of sulphat of iron 252 cubic inches of nitrous gas were thrown up, of which 180 were speedily absorbed. The same gas had been previously tried with the same test, and the whole was absorbed except a residue of 12 per cent. which was azot. This solution of iron then shewed the following appearances: 1st, with potash, a deep green oxyd of iron was separated, and a very sensible ammoniacal smell was given out: 2d, with sulphuric acid, white vapours were expelled, which were found to be nitrous acid:

^c Phil. Trans. vol. 73.

^f An. Chim. tom. 28. p. 123.

^g D° D° p. 181.

^h Expts. on Air, vol. 2. p. 13.

3d, tincture of litmus was strongly reddened by the solution, though the nitrous gas had passed through potash in its way to the solution of iron. From these trials the presence of an acid in excess, of nitric acid, and of ammonia were detected, and consequently some change must have taken place capable of converting the nitrous gas into nitrous acid, and of uniting azot and hydrogen (the constituents of ammonia) in such a manner as to produce this alkali from materials which gave no indication of it before mixture. For further certainty the solution was put into a retort, supersaturated with potash, and distilled gradually nearly to dryness. The distilled liquor had an ammoniacal smell and gave white fumes when a piece of glass moistened with muriatic acid approached it, and being afterwards saturated with this acid and distilled to dryness, 4 grains of pure muriated ammonia were collected. The first residue (or that of the sulphat of iron with nitrous gas and potash nearly dry) was then washed with pure water, which by subsequent evaporation gave 17 grains of nitre.

To complete the experiment, the gas that had escaped the first action of the iron solution, amounting to 72 cubic inches, was agitated with sulphat of iron and a large portion was absorbed. If it had contained the whole of the azot of the 252 inches of nitrous gas (amounting at 12 per cent. to 30.24) only 42 inches would have been absorbed, but instead of this the whole disappeared except 8.64 inches of azot. Hence it follows that the difference between 8.64 and 30.24, or about 21 inches of azotic gas had also been absorbed by the iron solution as well as the nitrous gas. It is to this absorption of azot that the authors of this experiment chiefly look for the explanation of the presence of the ammonia in the solution. Both nitric acid and ammonia are allowed to be formed in the experiment, the nitrous gas, say they, gains the oxygen necessary to complete its acidification by decomposing part of the water present. The hydrogen of the decomposed water then unites to the disengaged azot (present in the proportion of 12 per cent. of the entire gas) and forms ammonia, and again the nitrat of ammonia decomposes by double affinity an equivalent portion of sulphat of iron, so that the solution contains nitrat of iron, sulphat of ammonia, and sulphat of iron, and the residual gas is simply that portion of the azotic impurity of the nitrous gas which has escaped the complicated action of these affinities.

M. Humboldt then endeavours to confirm

this hypothesis of the presence of azot in nitrous gas being accidental and preexistent in the gas before the action of the iron solution (on which the whole of his eudiometric system is founded) by analyzing the same nitrous gas by oxymuriatic acid gas. By this reagent (allowing for corrections in the estimate on account of the impurity of the acid gas and of the water whereby the two gases are mixed) Mr. H. finds a larger residue of azot than when sulphat of iron is used to decompose the nitrous gas. Now the oxymuriatic acid will certainly absorb and oxygenate the nitrous gas, but, as the author of the experiment supposes, it will not act in any way upon any portion of azot that may be mixed with it as in the former case, nor will there be any ammonia formed in this instance, the presence of this alkali being absolutely incompatible with this acid. Hence the increase in the quantity of residual azot is supposed to be owing to the addition of that portion which, when the sulphat of iron was used, went to form ammonia, and which therefore may be now estimated. Thus, in the actual numbers of a given experiment (with the corrections that the reader may be aware of the difficulties that oppose a very accurate result) 100 parts of nitrous gas mixed with as much oxymuriatic acid gas left a residue of 20 parts of azot. The acid gas was previously found to be absorbed by water all but 10 per cent. of air nearly atmospheric, of which 4 parts were found to be oxygen and 6 azot; and consequently these 6 parts of azot must be deducted from the residue of 20, leaving 14 for the whole of the azot preexisting in the nitrous gas. On the other hand, 100 parts of the same nitrous gas analyzed by sulphat of iron left 11 parts of azot. Of this number 2 are to be deducted for the azot of the interstitial air of the solution, and the remaining 9 parts are the quantity of preexistent azot in the 100 parts of nitrous gas as indicated by the latter mode of analysis. Consequently the difference in the quantity of azot indicated by the two modes of analysis, that is between 14 and 9, or 5 parts, are supposed to be the azot entering into the composition of the ammonia which is formed only in the first instance.

Humboldt has shewn very satisfactorily that the eudiometrical mixture of nitrous gas and atmospheric or oxygen gas cannot be made to answer when performed over mercury, which were it practicable would be highly to be wished on account of the complication in the experiment caused by the action of water alone on

nitrous gas, and also of the air contained in all common waters. But when the mixture is made over mercury, though the nitrous gas unites with the oxygen as usual, the mixture remains in the gaseous or vaporous form for want of the contact of some fluid capable of absorbing the new products. Consequently the experiment must be made over water and not mercury.

The above experiments on the source of the residual azot and the deductions from them, have however been objected to by Berthollet, and every thing that comes from so excellent an observer deserves attention, though we cannot consider the objection as entirely valid. When nitrous gas is agitated with distilled water, a diminution of from 10 to 14 per cent. takes place, and as Humboldt has observed, nitrated ammonia is found in the water, which he attributes to the same cause as in the formation of the same compound by nitrous gas and a solution of sulphat of iron, that is, to a decomposition of part of the water, its oxygen saturating part of the nitrous gas to form nitric acid, and its hydrogen combining with the azotic impurity of the nitrous gas to form the ammonia. To this explanation Berthollet objects that the quantity of ammonia is extremely small compared to that of the nitric acid produced; that if potash be dissolved in the water the diminution of the gas is much speedier and no ammonia whatever is formed, but only nitric acid, which is found in the form of nitrat of potash when the water is examined; that the electric spark, according to Van Marum, causes the absorption of nearly three-fourths of the volume of the nitrous gas when over water, and the residue is azot; but when over mercury, only of about half its bulk; and from these and other observations he concludes that the azot left after all these operations is not a mere impurity of the nitrous gas, but is produced by the decomposition of the nitrous gas itself. Thus he concludes that water, potash, the electric spark, &c. have the power of effecting a decomposition of the nitrous gas neither by adding nor taking away any substance, but simply by concentrating the oxygen in one portion to its exclusion in the other. The portion in which the oxygen is concentrated is therefore converted to nitric acid, and that from which it is withdrawn is the residual azot gas. In further confirmation of this, the same chemist mentions that on exposing nitrous gas to a cold solution of sulphat of iron, and introducing phosphorus to the residue, it did not dissolve therein as phosphorus

does in pure azot, but only became soluble after a subsequent shaking with hydrosulphuret of potash, whence he would infer that nitrous gas is not so completely decomposed by sulphat of iron as by the hydro-sulphuret.

It has been mentioned that Humboldt lays much stress on the comparative test with oxymuriatic gas, and finds (as his theory required) a greater residue with this test than with that of the sulphat of iron. Berthollet however asserts that on operating with very pure nitrous and oxymuriatic gasses, adding the latter to the former very carefully to avoid the least super-saturation, the gasses so totally disappeared that no more than from 1 to 2 per cent. of the volume of nitrous gas remained at all, instead of 14, which was Humboldt's result. The great defect of M. Berthollet's explanation of the cause of the azot is, that the source of the hydrogen of the ammonia, allowed on all hands to be produced by the mutual action between nitrous gas and sulphat of iron, and even in a smaller quantity between nitrous gas and water, is totally unaccounted for, nor, according to the antiphlogistic system of chemistry, is there any substance present except water that can furnish it. If therefore some water is actually decomposed and its hydrogen thus employed, there is a surplus of oxygen which may go either to the complete acidification of the nitrous gas or to the complete oxygenation of the *sub-oxyd* of iron of the sulphat. The other part of the valuable research of Humboldt, consisting of many experiments with a view of finding the precise point of saturation between nitrous gas and oxygen, either pure or in atmospheric air, will be further noticed under the article NITROUS ACID, but it may be here mentioned that he considers this point of saturation of the two gasses to be (in bulk) from 2.6 to 2.5 of nitrous gas to 1. of oxygen, in which proportions, therefore, they form nitric acid.

Whatever may be the source of the azot left unabsorbed in the residue of nitrous gas, it appears by numerous experiments that nitrous gas *applied in a gaseous form*, can scarcely be depended on as an accurate and comparable eudiometer, and that the number of precautions required to use it with tolerable accuracy is too great to give any encouragement to adopt it as an universal instrument.

Of nitrous gas dissolved in a solution of iron.

The objections that prevail so powerfully against the use of nitrous gas do not apply in this case, and late observations have shewn that this test is the most expeditious and simple of

any known, and does not appear to yield to any in accuracy. Indeed it is no small presumption in its favour, that the results which it gives correspond very closely with those of the eudiometer of phosphorus, hydrosulphuret, &c. whilst the simple nitrous gas eudiometer always differs from the others in a very remarkable manner. In using this compound solution, no calculations relative to other gases are required, but the absorption of air, on mixture of the gas to be examined with the solution, simply indicates the quantity of oxygen contained in the air.

This eudiometer (first adopted by Mr. Davy)¹ is as simple as possible. The solution is made by passing nitrous gas through green sulphat or muriat of iron dissolved to saturation in water. As the gas is absorbed the solution passes from olive green to a deep brown or almost black. A graduated eudiometer tube is then filled with the air to be examined, and put in contact with the solution, which by very gentle agitation will in a few minutes absorb all the oxygen and leave the azot untouched. (*The most convenient apparatus for this and other eudiometrical processes will be described in the Appendix.*) The only precautions required here are not to use the same solution twice, to keep it in a well-stopped bottle, and particularly to observe the time of the greatest diminution when used, for shortly after, the volume of the residual gas begins again to encrease, owing perhaps to the decomposition of the nitrous gas formed in the experiment. One cubic inch of the solution of moderate strength will absorb 5 or 6 cubic inches of oxygen, and therefore will be sufficient to analyze about 25 inches of common air.

Of the sulphurets as Eudiometers.

A mixture of iron filings and sulphur moistened with a little water, and kept in a close vessel for about twelve hours, was the eudiometer employed by the illustrious Scheele in his original experiments on the constitution of the air so early as the year 1779. The sulphur and iron unite by the help of the moisture, and a sulphuret is formed which has the power of very completely absorbing the oxygen from the atmosphere. With the simple apparatus of a small cup of this mixture, supported on a small pedestal in the midst of a jar, graduated and standing over water, this excellent chemist observed that an absorption soon visibly took place, and the water gradually rose in the jar during about eight hours, after which no further rise took place, and the entire contents were di-

minished about 9 parts out of 33 (the entire capacity of the vessel deducting the space occupied by the cup) or about 27 out of 100. To ascertain whether any notable change took place in the atmosphere during the variety of seasons through the year, he continued them with the same apparatus for a twelvemonth, but the absorption was always from 24 to 27 per cent. without any connection with the apparent state of the atmosphere.

This is to be considered as a most valuable elementary experiment (and quite in the manner of this excellent philosopher, that is, of doing great things with simple means) but circumstances which he could not then foresee render a more minute accuracy necessary to bring this test to the perfection of which it is capable. Dr. Priestley found that a mixture of moistened sulphur and iron filings after a certain time produces a quantity of hydrogen gas, which, when the test is used eudiometrically, will mix with the azotic gas and enlarge the bulk of the residual air, thus giving the appearance of a less absorption of oxygen than has really taken place. Hence the absorption should be registered at the time of the greatest diminution. The sulphureted alkalies or alkaline earths are equally efficacious with the mixture of sulphur and iron filings, and being in a liquid state they may be shaken with the air, which will so much shorten the operation that five or ten minutes in this way of application will suffice, which is often a real convenience.

The sulphuret of lime is made by boiling together sulphur, lime, and water. For this purpose mix one ounce of flowers of sulphur with a little pure water, put it into a glass matrafs and add about a quart more of water, and 3 ounces of lime broken into small fragments; stop the vessel loosely with a cork and boil gently for about an hour with frequent shaking. By subsidence the liquor soon becomes clear, and is then to be poured without delay into close-stopped bottles. The liquid sulphuret of potash or soda will answer as well, and these solutions may be made much more concentrated than the liquid sulphuret of lime. The simple apparatus of Dr. Hope (*see the Appendix*) may be conveniently used in this eudiometrical process. The air to be examined and the liquid sulphuret of lime are shaken together for five or ten minutes, after which the absorption is complete.

Guyton has proposed to hasten the absorption by heating the solution, but it appears that

¹ Journ. Royal Institut.

with a very little excess of heat there is danger of getting a considerable admixture of sulphuretted hydrogen.

Even in the cold, and when the process has been put an end to as soon as the absorption is complete, the residual azot must contain some sulphuretted hydrogen, since it has the strong smell peculiar to this gas, but the quantity is so small, that though subsequent shaking with pure water will not free it from this smell, no perceptible diminution is found. The residual gas therefore may be estimated as entirely azot without danger of error.

A more important circumstance has been mentioned by Marti^k, which if accurate, renders another precaution necessary. It appears from this that liquid sulphuret of lime (and probably the liquid alkaline sulphurets also) are capable of absorbing a certain portion of azot as well as oxygen, if it has not previously been exposed to air for a short time. The quantity of azot thus absorbed, however, is very small, though sufficient to make a very sensible difference in the calculation. By the experiments here given the absorption of azot is in direct proportion to the quantity of the solution. Thus when one part of common air was shaken with 20 parts (in bulk) of the liquid, the absorption was 26 per cent. but of these only 21 are found to be oxygen, and therefore 5 of azot are also absorbed. To prove it, the experiment was repeated with the same solution that had served for the previous experiment, and the absorption was now only about 21 parts, shewing therefore that the sulphuret had been saturated with azot by the former process. The same solution was further shaken with pure azot but with no diminution of the latter, whereas when a fresh portion of the solution was used about .05 of the azot were absorbed. With a perfectly fresh sulphuret that had been closely kept from air till cold, and then used immediately, the absorption of azot was much greater, for a twentieth of its bulk of common air shaken with it for a few minutes diminished full one half, and consequently the air had lost both all its oxygen amounting to about 21 per cent. and also 29 of its azot. But it is never necessary to use such a large proportion of the solution, a quantity equal to once or twice the bulk of the air being amply sufficient, and for perfect accuracy it will therefore be adviseable previously to shake it with a little common air, (or in a bottle which it only partly fills) after which it may be safely confided in, as being a very excellent and

accurate eudiometer. The same observer also confirms the fact now so well established, of the almost unvarying proportion of oxygen during all the sensible changes of the atmosphere, by a series of observations carried on for a long time at Altafulla in Spain, the above eudiometer shewing at all times from 21 to 22 of oxygen.

Of Phosphorus as an Eudiometer.

Phosphorus is capable of two modes of combustion when in contact with common air; the one, rapid, with evolution of great heat and light, the other slow, with the production only of white fumes strongly luminous in the dark. The latter takes place when the temperature is not higher than about 90° or 100° (more or less according to the purity of the phosphorus), and it is this mode which is chiefly used for eudiometrical purposes. It is simply and conveniently performed by fixing one end of a long thin cylinder of phosphorus in a bit of a glass tube run through a cork which loosely fits the open end of the glass tube or narrow jar in which the air is contained, and immersing the lower part of the jar in cold or cool water. As soon as the phosphorus is in the tube, it becomes surrounded with a white fume, luminous in the dark, which slowly falls to the bottom and is absorbed by the water, during which time the contained air gradually lessens and the water rises in the tube. The absorption is complete when the contained gas becomes clear and no longer luminous, which, in a small tube with a stick of phosphorus that traverses nearly the whole length of its bore, and at a heat of about 70, requires from half an hour to an hour. The process succeeds equally well though in a longer time at a lower temperature: a heat of about 80 or 90 is as much as the phosphorus will usually bear without actually taking fire, which may readily be avoided by observing that it melts and becomes glossy on the surface just before it kindles.

Several facts are to be noticed on this eudiometer, the exact operation of which has been ascertained by Goettling, Berthollet, and other chemists. When phosphorus is exposed to air at any temperature below that at which it kindles, the first effect seems to be a solution of a minute portion in the azot of the surrounding air, and this phosphorized azot then immediately unites with the oxygen, becomes thereby luminous, and phosphorous acid absorbable by water is generated. Hence it is (strictly speaking) the phosphorus dissolved in the azot that is the eudiometer in this instance,

and in confirmation of this it may be observed that phosphorus is not luminous in perfectly pure oxygen gas, but appears to remain quite inactive and untouched by it at any temperature below the point of kindling, after which indeed it burns with most intense heat and splendour. On the other hand if the purest possible azot is passed through water into a jar full of water and containing a stick of phosphorus, the gas becomes luminous only for a very short time (owing apparently to a minute quantity of oxygen absorbed from the water) after which, when this is consumed, the light ceases, but the azot continues to saturate itself with phosphorus, and in so doing it expands about $\frac{1}{40}$ in bulk.¹ If now a bubble of common air or oxygen is let up to this phosphorized azot (the phosphorus itself being removed) the gas immediately again becomes luminous and continues so till the oxygen is exhausted. By phosphorus therefore we are furnished with a valuable test of the purity of azotic gas, for when this air is pure, no luminous vapours should be produced, but at the same time a solution of part of the phosphorus is effected, which is proved by afterwards throwing up a portion of common air and observing white luminous fumes. Berthollet has also observed^m that when the azot remaining after the action of any sulphuret on common air is put in contact with phosphorus, it then does not acquire the property of being luminous with oxygen, and even if a liquid sulphuret is placed in a vessel full of azot already phosphorized, it loses the luminous property. This is a curious fact which merits further enquiry.

It has been questioned whether the above slow combustion of phosphorus abstracts the whole of the oxygen. After all absorption has ceased, the apparent loss is from 20 to 21 per cent. whereas in the eudiometers of liquid sulphuret, and of the solution of iron with nitrous gas, the absorption is generally from 21 to 22. Were this small difference only observed in a few trials it might well be attributed to accidental variations and the degree of imperfection always attending these minute and delicate operations. But as the difference is constant some cause must be sought for to account for it. It is certainly not at all improbable that no two eudiometric substances should have precisely the same affinity for oxygen, or should agree in abstracting every particle of it from the azot with which it is so intimately mixed in the atmosphere. The valuable researches of Berthollet on the effect of proportional quantities in mo-

difying chemical affinities render it highly probable that (rigorously speaking) there is no such thing as a perfect decomposition of any actually existing chemical compound by the action of any simple substance, and the difficulties of accurate research on gaseous bodies are much greater than in any other kind of chemical investigation. In the present case however part of the supposed incomplete action of the phosphoric eudiometer may be shewn to be only apparent, from the circumstance that the azot increases in bulk about $\frac{1}{40}$ by saturation with phosphorus, which of course proportionally diminishes the apparent absorption. For perfect accuracy therefore the bulk of the residuum must be diminished by $\frac{1}{40}$, and this diminution must be thrown in to the side of the oxygen absorbed.

On the whole however, whenever the results of eudiometric experiments are given, the mode of ascertaining the quantity of oxygen should be expressly stated.

In analyzing an air much more oxygenous than the atmosphere, the phosphoric eudiometer is much less rapid and powerful in its operation, as the solubility of the phosphorus decreases in proportion to the diminished quantity of azot. Hence the other methods are preferable, or else the air to be examined may be diluted with azot or atmospheric air whose composition is previously known.

In these operations, as in all others on gaseous bodies, the corrections requisite for variations in pressure and temperature must be accurately attended to; there can be little doubt that many of the apparent anomalies found in all promiscuous collections of experiments on gaseous bodies are to be attributed to this cause. The mode of making these corrections will be given under the article GAS.

EVAPORATION. That very important part of the theory of heat which is connected with the formation of vapour, has been described under the article *Caloric*.

As a part of technical chemistry the process of evaporation is of extreme importance, as being essential to an infinite number of chemical processes both for experiment and manufacture. As the consumption of fuel is an object of first importance in all large evaporations, numerous experiments have been made to ascertain the greatest possible effect of combustibles in evaporating the watery part of saline and other solutions. It seems to be now well ascertained that more liquid is evaporated by a given por-

¹ Berthollet.

^m Journ. Polytech. part. 3.

tion of fuel when the liquor is kept at the boiling point than at any inferior temperature, and hence this is the heat generally employed, except a lower temperature is required for particular purposes. Evaporation is greatly increased by the agitation of the air on the surface of the heated fluid, but again as this has an equal effect in cooling the whole mass, it is a matter of great doubt whether the additional strength of fire required to counteract this effect will not in most cases destroy any economical advantage which may be proposed from this circumstance. For further practical observations on the construction of vessels for evaporation, the reader is referred to the article *Muriat of Soda*, and to the *Appendix of Chemical Apparatus*.

EXCREMENT (*Animal*). Even this most disgusting of all subjects has not escaped the minute researches of certain chemists. The cupidity of the alchemists was excited by some wild dreams of being able to extract from this substance an oil capable of fixing mercury (the first step to its supposed conversion into gold), and hence many experiments were undertaken upon human excrement, on which subject we shall not detain the reader. Homberg (one of the most respectable of the earlier chemists, who were still hesitating how much to reject of the fanatical visions of the alchemists) made a number of experiments on this substance, one of the results of which was the discovery of the *pyrophorus*, which bears his name, and which is now made by a perfectly inoffensive process.

The dung of different animals is used for a variety of important purposes. That of the herbivorous quadrupeds appears a mixture of bile and animal fluids, with a considerable portion of the fibrous or least digestible part of vegetable food. Hence the great use of camel's dung in Arabia and Egypt as fuel, being the chief and almost the only substance procurable for the purpose. A considerable quantity of ammonia is always produced by the burning of dung, from which, mixed with sea-salt, the first sal-ammoniac was procured. Cow-dung is of no small use in a number of processes for the preparation of cloth either for dyeing or bleaching. It mixes uniformly with water, and possesses cleansing powers similar to those of soap. The excrement of dogs and carnivorous animals is distinguished for its excessively offensive smell and the extremely corroding effect which it has upon organized matter, when the putrid fermentation is established. It is used in the preparation of **LEATHER** by *tawing*, as it is called, and its effect is first to loosen and destroy the

adhesion of the hair, then to render the whole skin extremely flexible and open in texture, and if the process is continued only a few hours too long, the whole consistence of the skin is destroyed, and it falls to pieces like a mucilaginous jelly. If the process of analysis were less repulsive, the examination into the properties of this powerful agent would prove interesting.

EXTRACT (*Vegetable*). *L'Extractif*, Fr. *Extract-Aufzug*, Germ.

There are few terms used in a more vague and indeterminate sense than that of extract. In common acceptance it is understood to mean that mixed mass of vegetable principles which is *extracted* from almost all parts of plants, by maceration, infusion, or decoction in water or alcohol, and evaporation of the solvent liquor to a greater or less degree of dryness. For example, when a strong decoction of liquorice root is evaporated with due precaution, there remains at last a black sweet coherent mass, which is the common Spanish juice or *extract* of liquorice. The term extract therefore of itself only describes the mode of formation, and that obviously by so general a term that a vast variety of vegetable principles may be included in it, all indeed that are soluble in the menstruum employed. But besides this general sense of the term, modern chemists have also adopted it to express one of the immediate principles, which there is good reason to suppose exists in all vegetables, possesses characteristic properties that distinguish it from mucilage, resin, and the like, and forms a very large share of all the common extracts, from whatever plants or parts of plants they are procured.

The preparation of the common extracts is peculiarly a branch of pharmacy, for the object for which this process was invented was to concentrate in a small and soluble mass all the medicinal virtues of entire vegetables or parts of vegetables. Thus jalap root contains parts soluble in water and alcohol, in which the medicinal power resides, but mixed with a large quantity of mere inert woody fibre, and hence an extract affords a means of separating the former from the latter. The medical and purely pharmaceutical part of this subject, which includes a variety of important facts concerning the use and preparation of extracts, is foreign from the present object.

The general process of preparing an extract where the menstruum is water, is as simple as possible. The substance employed is first bruised, rasped, or divided in any other way, then boiled with water once or oftener, so as to make a

very strong decoction, which is then evaporated generally by a boiling heat, till of a thick treacley consistence, after which it is dried to the degree required over a stove, or in some gentle heat to avoid the burning and consequent destruction of the medicinal powers, which would ensue were not the heat moderated. The particular precautions required for certain of these extracts need not here be enumerated.

The spirituous extracts, or those in which the menstruum is alcohol more or less diluted, are prepared in the same general way. As the substance extracted by alcohol is chiefly resin, these extracts are often called resinous extracts or artificial resins.

When the vegetable employed is a succulent herbaceous plant, the extract is often made without the addition of water, merely by putting the fresh plant under a strong press, forcing out all the natural juice, and evaporating it slowly to the due consistence. The extract of hemlock is made in this way. These preparations are also called with more perfect accuracy *Inspissated Juices*. The gum resins are properly the native juices of plants, inspissated by the evaporation of the watery part either in the sun's heat or by artificial fire, or sometimes by both. The catechu is an inspissated juice of this kind, and is composed chiefly of tan brought to a state of dryness.

Chemistry is indebted to Fourcroy for a very valuable research into the purely chemical nature of extract, contained in his elaborate analysis of the cinchona of St. Domingo: ^a and to Vauquelin ^b for an excellent enquiry into the same subject connected with the analysis of the sap and native juices of the succulent plants. All these memoirs throw much light on the nature of extract, though many difficulties still remain.

Fourcroy's operations on the cinchona, as far as relates to extract, are the following. A pound (16 ounces) of the cinchona reduced to powder was boiled twelve times successively for a quarter of an hour, in about 26 lb. of water each time. The first decoction was of a deep brown red, very bitter, and strongly frothed in boiling. It yielded by evaporation in a gentle heat 5 oz. 7 grs. of a brown dry extract. The second decoction was much less coloured, and gave only 9 drams of extract: the third gave only 2 grs.; and the sensible qualities of each decoction regularly diminished to the twelfth, which was little else than pure water. The entire quantity of extract obtained was 9 oz. 56 grains. A

second series of decoctions was made in precisely the same way and with the same quantities, but with this difference, that each decoction was allowed to cool before evaporation, in which time the fix first deposited, in decreasing proportions, a quantity of black tenacious extract, apparently insoluble in cold water. The supernatant liquors were then united, and the whole evaporated to 2 lbs. and the deposit on cooling was added to the other extracts, which all together amounted to almost 2 ounces less than the quantity obtained in the former way, which therefore remained in the 2 lbs. of decoction. This last on mixture with alcohol deposited about an ounce of a whitish cohesive mass, evidently different from the black extractive deposit, and was mucilage. Alcohol therefore appearing a useful reagent in this analysis, the black extract separated from the decoctions by mere cooling was treated in this way, to determine whether it was simple or compounded. Accordingly alcohol was boiled on it, and dissolved all but about $\frac{1}{20}$, which remained in the form of a fine red powder. This last digested with cold water lost a third of its weight of mucilage, similar to that precipitated from the decoction, and the remainder was, as before, a fine red powdery substance, the nature of which will be presently mentioned. The alcoholic solution was then let to stand exposed to air for some days, when it deposited a small quantity of brilliant crystalline grains. It was then mixed with water, and in some hours there separated a number of white flocculi. Lastly, the alcohol and water were totally evaporated, and a large quantity of extract remained. By repeating this mode of analysis with the entire extract obtained by the first process (which was therefore the whole of the matter which a pound of cinchona would yield by boiling with water to exhaustion) all the above substances were obtained in the following proportions:

	oz.	grs.	grs.
Mucilage - - - - -	1	1	0
Crystalline grains separated from the solution - -	—	1	0
Flocculi separated by adding water to the solution -	—	1	12
Red powder insoluble in alcohol -	2	0	0
Extract left at last - - - -	7	0	44
Loss - - - - -	3	—	—
	9	0	56

^a An. Chim. tom. 8. & 9.

^b Ditto, tom. 31. and Memoire sur le principe Extractif. Jour. de Pharmacie, p. 132.

It appears therefore that the extract is in by far the greatest proportion, which, with the red powder, are the only substances to be particularly considered in this place. It may be just added that the mucilage very closely resembled the common gum-mucilages, the crystalline grains were insoluble in alcohol and in cold water, but yielded to a large quantity of boiling water, dissolved in the alkalies and gave some ammonia by distillation; but the exact nature of this substance is not known, and the flocculi resembled in every respect the gluten of wheat.

The red powder the author shews to be clearly different from resin or any of the supposed immediate vegetable principles. Though its insolubility in water would make it approach to the nature of resin, its equal insolubility in alcohol refutes this conjecture. Neither does it melt at a gentle heat, but it unites with alkalies immediately and inseparably, in both of which properties it differs from resin. Its colour is extremely durable and little altered by the oxymuriatic acid. The true nature of this red powder seems to be in a good measure explained by that of the extract.

This extract is obviously from its quantity and its sensible properties the most important of the soluble parts of the cinchona. When quite dry it is hard and brittle and shining in its fracture, of a black or deep brown colour, and intensely bitter. Neither gum nor resin resembles it in the united properties of being soluble totally and permanently in hot alcohol, and insoluble in cold water, but dissolving entirely in hot water, with the separation of the greater part (but not the whole) on cooling, unless largely diluted. The oxymuriatic acid was tried as a reagent on a small portion of this extract dissolved in a large quantity of water. The first effect of the acid passed in the form of gas through the solution, was to give it a clear red colour and to separate a red flocculent powder. A greater quantity of the gas deprived the liquor of colour and much lightened that of the powder. After separating all the red flocculi, which amounted to $\frac{2}{3}$ of the extract originally employed, the liquor now saturated with the gas gave by evaporation a black acerb matter mixed with muriatic acid.

This extract therefore appears by this analysis to be composed of two parts, one capable of being converted by oxymuriatic acid into a red pulverulent substance, and the other not acted on by this substance. On examining the above red powder it was found also to resemble very closely the red powder mentioned above as one of the constituents of the cinchona. The author

therefore concludes that this last consists of the true extract altered by absorption of oxygen, since a similar powder is produced by the direct action of oxymuriatic acid on extract; and infers that the oxygenation in the former case is produced by the gradual action of the atmosphere on the surface of the decoction during the long exposure in the time of evaporation. In confirmation of this hypothesis he adds that the quantity of this red insoluble powder generated, is in direct proportion to the time of exposure to air, and hence as it appears to be nearly inert on the human constitution, it has been lately thought proper in pharmacy to avoid this deterioration of the extract by boiling the decoction only for a few minutes and in a covered vessel.

Extract when heated *per se* to decomposition gives, besides the usual vegetable products, a small quantity of ammonia, which indicates the presence of azot, but whether this is an essential part of extract, or only arises from some adhering portion of gluten, is very doubtful.

A very pure extract has long been known in pharmacy by the name of *Essential Salt of Count la Garaye*, who first conceived the idea of preparing the supposed essential or finer part of the soluble matter of cinchona and other substances by infusion in cold water, assisted by extreme and long continued agitation. This last was first performed by small mills and a very complicated apparatus, but was afterwards found unnecessary. This preparation is made simply by adding cold water to the powdered bark, shaking them together frequently during a maceration of two days, and then slowly evaporating the infusion, which is strongly impregnated with the sensible and active properties of the cinchona. The extract thus prepared, if the evaporation be well managed, has a fine granular crystalline appearance, whence the inventor took it for an essential salt. It is scarcely soluble in cold water and a good deal resembles the red powder, the supposed oxygenated extract; but it has not been examined in a very satisfactory way.

The above are the general properties of the extract obtained by the decoction of the peruvian bark, and will apply with some latitude to that of most other barks and woods. With many, however, a large portion of tan is mixed which may be separated by solution of isinglass, or any other gelatin.

We proceed to the properties of the extract as contained in the native juices of plants, and therefore probably in a purer state, at least being already in a state of solution, all the changes liable to be produced by decoction with water

are avoided. The experiments of Vauquelin on this subject are here of chief importance (*see the article SAP*). When the sap of any tree is first drawn, it is always colourless or nearly so, but in the process of evaporation it invariably becomes brown, and a certain though small quantity of pulverulent insoluble brown or red matter is precipitated. The extract obtained by evaporation to dryness is always a very mixed substance, containing, often tan, often saccharine mucilage, and always several earthy and saline matters, among which are lime, potash, acetous acid, and generally ammonia. The existence of acetous acid in all extracts whatever, is ascertained by pouring a few drops of sulphuric acid upon them, which immediately produces a pungent agreeable vapour of acetous acid, and with sufficient quantities this acid may be collected in a receiver.

Ammonia is also discovered in extracts, for if some quick-lime be rubbed with any of them, the vapour of this alkali immediately arises. All the extracts made by water constantly attract moisture from the air, whereby in no great length of time they grow mouldy, to the great detriment of their medicinal virtues. This disposition to moisture is doubtless principally owing (as Vauquelin has observed) to the acetite of potash and ammonia which they contain, and which are very deliquescent salts.

All the soft extracts have also an excess of this acid, and hence they invariably redden litmus.

Extract appears to form a great portion of the colouring matter of vegetables, the affinity of which with different mordants, has been amply detailed under the article Dyeing. Thus if a solution of alum be added to any extract dissolved in water, a copious coloured precipitate is formed, insoluble in water, and consisting of extract intimately combined with alumine, whilst the supernatant liquor is rendered nearly colourless. Most of the metallic salts also occasion a precipitate consisting of the extract with the metallic oxyd. The colour of the greater number of extracts is brown, red, or fawn.

From the foregoing observations it appears to be as clearly demonstrated as in any other case of vegetable analysis (in itself difficult and complicated) that there exists a peculiar and immediate vegetable principle to which the term extract may be given, that it is almost invariably contained in greater or less degree in the part which is soluble in water, that it is naturally colourless when in solution in the vegetable juices, but when condensed in the solid parts,

or when exposed to air, or to heat, it always becomes more or less brown and coloured, that it is freely miscible with water in the state of colourless solution, but when altered by long exposure to heat and moisture it becomes scarcely soluble in cold water, and much of it spontaneously separates from its solution by hot water, in proportion as it parts with heat; that it has a very strong affinity for alumine and metallic oxyds, separating them from their respective solutions, and forming compounds scarcely decomposable but by the agency of fire; and lastly that it is found by destructive distillation to be composed of carbon, oxygen, and hydrogen, and probably a small portion of azot. These chemical properties are sufficient to distinguish it from every other of the immediate vegetable principles, but to them is added by some acute and excellent chemists, another characteristic namely, a strong affinity for oxygen, to which the colouring and difficult solubility in water are attributed. This character, however, cannot be admitted without some limitations.

When a colourless juice, such as the sap of any tree, is heated in an evaporating vessel, it gradually becomes of a dark brown, owing, as it is said, to the oxygen which the extract absorbs from the air. This opinion is certainly of itself sufficiently probable, but it also appears that the same change of colour takes place in vessels nearly closed as soon as the juice becomes heated, for Vauquelin^c adduces this as a convincing argument to shew that it does not depend on a concentration of the extract. But it is difficult to conceive how sufficient oxygen should be acquired for this purpose from the narrow aperture of a vessel through which a quantity of heated vapour must be constantly expelled; and if the first change will take place independent of the effect of the external air, it deserves inquiry by experiment, whether an extract similar to that produced by evaporation in open vessels, would not be obtained by the same process in closed vessels. Again, the chief argument adduced for the successive oxygenation of extract, is the formation of the red-brown pulverulent and sometimes crystalline deposit, from the watery solution of extract after long evaporation in open vessels, confirmed by the immediate production of a similar deposit by the oxymuriatic acid. But it has not yet been at all proved by analysis that this deposit differs from extract in no other circumstance than in an increased quantity of oxygen. The exact

^c Jour. de Pharmacie.

nature of this singular product still requires further explanation, but it appears to be a very intimate union of vegetable matter with lime, for when calcined, the residue is chiefly carbonate of lime. Neither is the production of this substance by passing oxymuriatic acid through a solution of brown extract, conclusive of its being generated by the simple union of oxygen with extract, without being confirmed by a full examination of the solution that remains, and a proof that all the oxygen of the acid had passed into the red powder, and into that only. It cannot be doubted that in the course of common evaporation of the decoction or infusion of extract, the length of time to which it is exposed to air much influences the quantity of this supposed oxygenated extract, but though the above-mentioned eminent chemists express their full conviction that the whole extract might be successively changed in this manner, it does not appear that they have ever effected this change even on any considerable portion of the extract, for in the experiments with oxymuriatic acid, after this had been added to full saturation, only 30 grains of the red powder could be obtained

from 72 of the extract. This opinion therefore of the spontaneous oxygenation of extract though ingenious, and by no means improbable, must still be considered as extremely hypothetical, and cannot be yet admitted as a distinctive character of this vegetable principle.

Much variety is found in the sensible properties of colour and taste, in the different extracts. The colour is generally brown or red with various modifications, and it is quite a characteristic of all the solid extracts to be deeply coloured, in which respect they differ essentially from mucilage, fecula, and many other vegetable principles.

Bitterness of taste is a much less constant character, and is even entirely absent from a very large number of individual extracts.

After all that has been done on this subject there is strong reason to suspect that this substance is one of those which the most easily enters into combinations with all the other vegetable principles, and probably unites with them so strongly, that no chemical process has ever succeeded in producing it pure and unmixed.

F

FAHLERZ is an ore of **COPPER**, which see.
FARINA. See **FECULA**.

FAT. For the properties of this substance see the articles **OIL**, *animal*, and **SEBACIC Acid**.

FEATHERS. The chemical composition of feather appears to be nearly the same as of hair, nail, cuticle, and cuticular shell, that is (according to Hatchett's admirable research on these substances*) to consist of little else than inspissated albumen, mixed with a very minute portion of gelatin. The latter however is so small that quill or feather freed from adhering oil, may be boiled for many days in water without any apparent alteration, the liquor having no sensible properties, giving no precipitate with tan, and a very small one with nitro-muriatic of tin. It is therefore only a very minute portion of gelatin that is extracted in this way. (See **ALBUMEN**.)

FECAL MATTER. See **EXCREMENT**.

FECULA. The term Fecula is generally applied to any fine pulverulent matter extracted from any part of a vegetable, simply by breaking down its texture, washing with water, and subsidence for a greater or less time. The fecula is the substance deposited at the bottom of the water. It is therefore in other words a most

minutely divided substance, capable of being for a time suspended but not dissolved in cold water or in the native vegetable juices. Of these the most important is the *Amylaceous Fecula*, or a nutritive insipid substance which is contained most abundantly in all grains forming the largest and most valuable part of their substance, and when separated, purified, and dried, is the common **STARCH**. The preparation of starch as a manufacture, will be described under that article, the chemical properties of pure fecula belong to the present subject.

Almost every part of vegetables will furnish this fecula, but it is particularly found in all grains or seeds of whatever kind, is united in them with an extractive and saccharine matter, sometimes with gluten and vegetable albumen, with mucilage or with oil. It is also contained copiously though comparatively in less proportion in most roots, particularly the tuberous and bulbous, in the medullary part of trees and plants, and sometimes nearly equally diffused over the whole plant as in many of the lichens and plants of a similar genus.

The extraction of the fecula is a very simple process, but from certain vegetables it can never

* Ph. Transf. vol. 90.

be obtained free from colour and taste. The root or grain employed must first be thoroughly bruised, rasped, or broken down in any way, and then washed with a quantity of cold water, which becomes immediately turbid, and if the fecula is white, milky; and simply holds the fecula suspended in a state of extreme division, but without dissolving any portion of it. This turbid water is then to be immediately separated from the fibrous pulp by a sieve, and allowed to remain at rest for a time, when the fecula will be found at the bottom, in the form of a very fine close-grained powder, but without any tenacity or cohesion, somewhat of the consistence of very fine wetted sand. It should then be washed repeatedly with abundance of water, till this comes from it quite insipid.

The extraction of fecula is therefore as simple as possible, consisting in fact only of a single operation, that of washing out with cold water, but it is only from grains and some roots that it can be procured so easily, for this simple method will not succeed in the nut or kernel seeds, in which the mixture of oil, fecula, and mucilage is so intimate, that both dissolve together into a milky emulsion when agitated with water; nor will mere washing easily separate the fecula from many of the juices, fruits, and soft parts in which it is intimately combined with mucilage, extract, and saline substances.

In all processes for the separation of fecula from other vegetable matters, it should be constantly kept in mind that only *cold* water is to be employed, for when hot it dissolves readily.

Pure fecula (taking starch for an example) is a white powder nearly if not absolutely insipid, somewhat adhering to the tongue, but readily softening down in the mouth into an incohering pulp. When examined with care in a strong light, and especially with the help of a lens, it is seen to be composed of small semi-transparent globules, with a fatty gloss^b and somewhat of a crystalline arrangement. When in mass and squeezed between the fingers, it breaks with a slight snap and a peculiar short feel not easily described. It is not easily moistened with cold water, on the surface of which it swims till thoroughly wetted.

Pure starch when heated strongly in the open air, passes from yellow to red and brown, softens, puffs up, exhales a white, pungent, acid-smelling smoke, exactly resembling that of mucilage or sugar, and leaves a spongy and rather bulky coal. The products of its distillation are, a water loaded with pyromucous acid, some

drops of a red or brown oil, much carbonic acid and hydrocarbonous gasses. The coal when fully calcined leaves slight traces of potash and phosphat of lime.

Starch does not easily alter in the air, but by very long keeping it runs into clots, and gets a sour and rancid smell.

Fecula rubbed with a little cold water only makes an incoherent mass, which on drying cracks into small pieces. With more water and a moderate warmth the mixture ferments faintly, and turns sour, probably by producing the acetic acid.

Boiling water however acts in a very different manner on fecula, for it speedily and totally dissolves it into a thick, tenacious, transparent gelly, as is daily seen in the domestic uses of starch. This gelly becomes thicker and more tenacious by long boiling, and it will unite with boiling water in any proportion.

By slow evaporation the gelly shrinks in every direction, and at last dries into a nearly transparent brittle substance, so closely resembling the evaporated solution of mucilage, that scarcely any difference can be found between the two.

The gelly when much diluted and dried on very extended surfaces gives only a kind of varnish and stiffness, for which it is of great use in the starching of linen.

Most of the acids dissolve fecula readily, especially when hot, and with nearly the same appearances that attend their action on mucilage and sugar. The nitric acid however does not produce with fecula the *Mucous* acid, as it does with gum mucilage.

The alkalies dissolve fecula with ease, but without appearing to produce any material change in its composition.

On the whole the resemblance between the amylaceous fecula and mucilage is so strong, that they may almost be considered as identical when each is brought to a state of solution in water.

Of the Green Fecula of Plants.

A vast number of the green succulent plants when exposed to slight pressure, give a very turbid green juice, from which a fecula subsides though extremely slowly, but it may be separated more readily by the filter. In this case the filtered liquor is tenacious, but clear and colourless, and a green pulp is left on the filter. Rouelle^c appears to have been the first who clearly shewed the nature of this fecula, and proved it to be not in the least similar to the amylaceous fecula, but to be composed of a substance re-

^b Fourcroy Syst. de Conn. Chim.

^c Procédés du Règne Végétal, &c.

resembling the gluten of wheat, intimately combined with a kind of resin soluble in alcohol, to which the green colour seems to be owing. The clear liquor from which this fecula has subsided also holds in solution another portion of gluten, or a similar matter.

Fourcroy considers this fecula rather as albuminous, and the substance contained in the clear liquor to be still more decidedly so, but Proust^d has pointed out some differences, and the other observations of this excellent chemist on this subject are also important.

When any of the green turbid juice of plants, such as of cabbage, hemlock, cress, and the like, is exposed to heat, it coagulates or becomes ropy, and soon a considerable quantity of a green tough glutinous mass separates in flocculi from the liquor, which is then left colourless. The clear filtered recent juice of plants also affords flocculi of gluten, which readily separate at a heat as low as 145°. At this temperature the albumen of an egg mixed with water will not coagulate. When the coagulated mass dries, it hardens into an elastic horny substance, which will not again unite with water. If this fecula either before or after coagulation by heat be kept under water, in warm weather it becomes offensive in a day's time, and by keeping it grows excessively putrid, with the fetor attending animal matter in a high state of decomposition. It appears to be to this that the excessive putrescency of hemp is owing whilst it is rotting in ditches to prepare it for spinning. The water in which this fecula has been long kept contains sulphuretted hydrogen, carbonat of ammonia, and some gluten dissolved in the ammonia.

To shew more decidedly that it is a kind of gluten rather than albumen which gives also to the liquor which holds fecula in suspension those chemical properties belonging peculiarly to animal matter, Proust made the following comparative experiments, taking the white of egg as the example of the purest albumen, and clear filtered cabbage juice for the other. Two matrasses were filled, the one with the cabbage juice, the other with some of a liquor made of the white of an egg beat up with a pint of water. On immersing them in water heated to 145°, the juice directly became turbid with cheese-like flocculi which fell to the bottom, but the albuminous water remained unchanged. Two more vessels were filled, one with the egg-water and the other with the juice diluted with twenty parts of water, and were slowly heated

to ebullition. In the latter the fecula separated totally from the water, but the egg-water only became opalescent, but not curdy, nor did it separate from the water, for albumen much diluted cannot by mere heat be freed from the water with which it is mixed. The albuminous water also keeps for some days clear and unaltered in a common temperature, but the diluted cabbage-juice turns putrid and begins to be curdy in a very short time, and sooner or later all the gluten is separated spontaneously in this way. Albumen also turns the red vegetable juices green, but the recent cabbage juice turns litmus red, and the washed fecula produces no change at all. Alcohol separates part of the albumen from the water in thin flocculi, but added to the juice it causes a heavy white powder to precipitate. All the acids, hydrosulphurets, and ammonia separate the feculous gluten from the juice but produce no change on albumen. No salt can deprive water of albumen, but this fecula on the contrary is precipitated from its watery solution by almost every saline substance. The feculae of most of these plants generally dry to a brown hard mass, but dried albumen resembles horn. From all examinations this kind of fecula is chiefly composed of a part nearly if not absolutely identical in nature with the gluten of wheat or blood.

The green fecula when put into potash partly dissolves therein, the insoluble portion falling to the bottom as a green sediment. The solution has all the characters of animal matters, exhaling ammonia, and blackening silver and many other metallic solutions.

When the entire green feculous precipitate, formed by heating the recent juice, is treated by alcohol, a portion only dissolves therein, leaving the true gluten untouched, and which amounts to about 80 per cent. of the entire precipitate. The alcoholic solution evaporated to dryness leaves (as Rouelle first observed) a soft green substance resembling a resin. Alcohol also added to the juices gives a precipitate of gluten, and unites with the resin. It has been doubted however by Parmentier whether this green resin is properly so called, since it does not deposit any thing on mixture with water as the tinctures of the true resins do. The oxymuriatic acid in a few days takes away all colour from this green resin, makes it ropy like turpentine, and its solution in alcohol will then grow turbid with water. The entire green fecula is reduced by oxymuriatic acid to the colour of dead leaves. The above resin gives a

^d Journ. de Phys. tom. 56.

clear solution with potash, and this colour will attach itself to silk, but it is not permanent.

On the whole therefore there is much reason to believe that the green fecula of plants consists of gluten intimately combined with a substance very nearly resembling a resin, and that it is to the former principle that the tendency to animal putrefaction and the ammoniacal products are owing, and in the latter the green colour seems entirely to reside.

See further the article GLUTEN.

FELSITE. See FELSPAR (*Compact*).

FELSPAR.^a *Feldspath.* Germ. and Fr.

Of this mineral there are the following subspecies, viz. Adularia, Common Felspar, compact Felspar, continuous Felspar, Labradore Felspar.

I. ADULARIA *Adular*, Wern. *Moonstone*, Kirw. *Feldspath nacré*, Haüy.

The colour of adularia is yellowish, greenish, or milk-white, and in certain directions it exhibits a play of silvery and pearly colours, owing to the different reflections of light from the laminæ of which it is composed. It occurs either in mass or crystallized. Its primitive figure is an irregular oblique angled parallelepiped, of which the faces in two directions are smooth and well defined and form an angle with each other of 90°, while the faces in the third direction are uneven, and form with the others angles of 120°. and 111.° 28'. Besides this, its primitive figure, it presents also the following modifications.

1. An oblique four-sided prism bevelled on two of its opposite sides.
2. An oblique four-sided prism with dihedral summits.
3. A six-sided prism with dihedral summits.
4. A double crystal, in the form of a rectangular four-sided prism composed of two half crystals united together in opposite directions.
5. A quadruple crystal, composed of four crystals of var. 2. united together by their summits and mutually penetrating each other, forming a kind of cross, consisting of four triangles united round a common centre.

The surface of the crystals is smooth and often striated longitudinally. They are for the most part middle sized or large. The external lustre is shining and somewhat pearly: the lustre of the principal fracture is bright shining; of the cross fracture shining, between vitreous and pearly. Its longitudinal fracture is perfectly foliated, its cross fracture is small conchoidal. It breaks into rhomboidal fragments.

It is composed sometimes of strait lamellar distinct concretions. It is translucent passing into transparent. Its hardness is inferior to quartz, but greater than that of common felspar. It is easily frangible. Sp. gr. 2.5 to 2.6.

When exposed to the blowpipe without addition it crackles a little, and at length melts into a whitish glass.

It has been analyzed with the following results by Chenevix and Vauquelin.

	Chen.	Vauq.
Silex - -	64.	64.
Alumine -	24.	20.
Lime - -	6.25	2.
Oxyd of iron	2.	0.
Water - -	1.75	0
Potash - -	0	14
	98.00	100.

Adularia was first found by H. Pini in the mountains surrounding Saint Gothard in Switzerland, especially in the summit called Mont Adula (whence its name). It here occurs in crystals, lining the cavities of gneiss and micaceous schistus. This mineral is also said by Jameson to occur in the Isle of Arran. The moon-stone of Ceylon, and a mineral discovered in Languedoc by M. Dodun and named by him *œil de poisson* (argentine felspar of Kirwan) are also considered as varieties of adularia.

II. COMMON FELSPAR. *Gemeiner Feldspath*, Wern.

The colour of this mineral is milk-white, yellowish, greyish and reddish white; also wax yellow and ochre yellow; flesh red, blood and brick-red; leek green, mountain green, and sometimes though rarely verdigris-green. It occurs in mass, disseminated, in rounded fragments or crystallized. Its primitive form and the other varieties of crystallization that it assumes are the same as those of adularia: it has also been found in ten-sided prisms with dihedral or other variously modified summits. The crystals are for the most part small and middle-sized. Externally felspar is more or less shining; internally it is the same, with a lustre between vitreous and pearly. The longitudinal fracture is perfectly lamellar; the cross fracture is fine grained uneven passing into splintery. Its fragments are rhomboidal with only four shining faces, the other two being nearly dull. It varies from translucent to opaque. It occurs often in granular concretions, either large or small. It

^a Haüy, Brochant, Kirwan, Jameson.

is not so hard as quartz, yet will scratch glass: it is brittle and easily frangible. Sp. gr. 2.27 to 2.70.

It melts before the blowpipe without addition into a white somewhat translucent glass.

Felspar has been often analysed and with very different results. The three last analyses of this substance and perhaps the most to be depended on, are, one of common felspar and another of felspar from the sand of Ceylon, by Chenevix, and one of the green Siberian felspar by Vauquelin.

	Com. F.	Ceylon F.	Siberian F.
Silex - -	64.	— 68.5	— 62.83
Alumine - -	24.	— 20.5	— 17.02
Lime - -	6.25	— 7.	— 3.
Oxyd of iron	2.	— 1.5	— 1.
Potash - -	0	— 0	— 13.
	<u>96.25</u>	<u>97.5</u>	<u>96.85</u>

Felspar when exposed to the weather acquires gradually an earthy appearance, and at length passes into porcelain clay. It also occurs in a state of semi-decomposition in several varieties of granite and porphyry, where it cannot have been affected by the atmosphere. When in this state it is usually of a yellowish or reddish-white colour, a faintly glimmering lustre, and a fracture imperfectly foliated passing into earthy: it breaks into indeterminately angular fragments, is opaque and considerably softer than common felspar. A very light coloured variety was analysed by Vauquelin, and found to contain

Silex - - -	74
Alumine - -	14.5
Lime - - -	5.5
	<u>94.0</u>
Loss - - -	6
	<u>100.</u>

Some of the coloured translucent varieties of felspar contain particles of mica dispersed through their substance, and these when the stone is exposed to the light form so many luminous points, which relieve the colour of the felspar and give the whole a spangled appearance that has a pleasing effect: in some instances however these brilliant particles seem to be occasioned merely by fissures in various directions. When felspar exhibits this appearance it is called *Aventurine* (a term also applied to a similarly glittering variety of QUARTZ). The green Siberian felspar sometimes contains

spangles of a remarkably brilliant silvery mica, forming a very elegant aventurine. Another fine variety has been procured from Cedlovatoï, an island in the White Sea, not far from Archangel, consisting of a semitransparent hyacinth-brown base with gold coloured spangles. The aventurine of Spain is the most familiar to European lapidaries, but this is a variety of quartz.

Common felspar is the most generally diffused, both as to its local and geological situation, of any other mineral except perhaps quartz. It is an essential constituent of granite and gneiss, and frequently occurs in micaceous and argillaceous schistus: it forms a large proportion of all filenite, and is contained abundantly in almost all porphyries: it is occasionally though rarely found in primitive limestone: it abounds in primitive, transition and secondary grunstein, and frequently though in smaller proportion in most of the other rocks belonging to the transformation: it also abounds in the greater part of the real lavas.

III. COMPACT FELSPAR. *Dichter Felspath.* Emmerl. *Felsite*, Kirw.

Its colour is bluish white passing into sky-blue, or greenish-white passing into brownish-green. The blue variety occurs in mass, the green is either disseminated or crystallized. Its lustre is glistering. Its fracture is very imperfectly lamellar approaching to splintery: its fragments are indeterminately angular: it is feebly translucent, and though hard considerably inferior in this respect to quartz.

Before the blowpipe it is difficultly fusible without addition, into a frit or imperfect glass. It has not been analysed.

The blue compact felspar was discovered by Widenmann at Krieglach in Stiria, forming a granitic mass with white quartz and silvery white somewhat unctuous plates, which have been considered by some mineralogists as mica, by others as talc. The green varieties occur in green porphyry and grunstein.

IV. CONTINUOUS FELSPAR, Kirw.

Its colour is reddish-grey or flesh-coloured, or pale reddish yellow, or olive green. It occurs in mass and generally contains hornblende or common crystallized felspar dispersed through it in various proportions. It is sometimes dull but generally possesses a feeble glimmering lustre: it is translucent at the edges: its fracture is fine-splintery passing into uneven earthy; its fragments are indeterminately angular. Its hardness is fully equal to that of common felspar and it is less brittle.

It melts at a high heat into a porous porcelain mass. It appears to be nearly connected with transition grüstein, and probably forms the basis of some of those porphyries which are commonly ranked as hornstone porphyries: indeed certain varieties of this and splintery hornstone resemble each other so closely in their external characters that it is by no means easy to ascertain to which species they belong. Hornstone however is in general both harder and tougher, and is infusible *per se* before the blowpipe, whereas continuous feldspar is fusible, though it often requires for this purpose a very high and long continued heat.

V. LABRADORE FELSPAR. *Labradorstein*, Wern. *Feldspath opalin*, Haüy.

The proper colour of this mineral is smoky-grey or dark ash colour, but on account of the small crevices between the lamellæ of which it is composed, it presents a most beautiful play of vivid tints varying according to the position in which it is viewed: of blue it exhibits all the varieties from violet to smalt-blue; of green it displays the pure emerald green and various other tinges approaching to blue on one hand and yellow on the other; of yellow the usual shades are gold and lemon yellow verging into deep orange and thence into rich copper-red and tombac brown. The parts exhibiting these beautiful colours are disposed in irregular spots and patches, and the same spot if held in different positions displays various tints. It has hitherto been found only in detached rolled fragments. Internally it is shining passing into splintery, with a lustre between pearly and vitreous. Its principal fracture is perfectly lamellar in two directions, the lamellæ crossing each other at right angles; its cross fracture is somewhat conchoidal: it breaks into rhomboidal fragments with four specular faces. It usually exhibits large granular and sometimes though rarely strait lamellar, distinct concretions. It is strongly translucent passing into semi-transparent. Sp. gr. 2.6 to 2.7.

It is fusible without addition before the blowpipe into a white enamel.

The only analysis that has yet been made of this mineral is by Bindheim, according to whom it contains

Silex	- - - -	69.5
Alumine	- - - -	13.6
Sulphated lime	- - - -	12.
Oxyd of copper	- - - -	0.7
Ditto of iron	- - - -	0.3
		96.1
Loss	- - - -	3.9
		100.0

It was first discovered by the Moravian missionaries on the Island of St. Paul on the coast of Labrador, and has since been found in Ingermannland in Norway, and in the vicinity of Lake Baikal in Siberia. It is sometimes accompanied by mica, black schorl and iron pyrites.

It is in considerable estimation on account of its beautiful colours for ornamental purposes.

On comparing the results of the analysis of feldspar by Vauquelin and Chenevix, both of them chemists of acknowledged ability and scrupulous accuracy, it is impossible not to be struck with surprise at the remarkable difference which appears between them. That potash should appear in one analysis and not in the other is no extraordinary circumstance, because without a particular examination for this very object the potash would remain undetected and its amount would be transferred to the general account of loss: the loss therefore in Mr. Chenevix's analysis ought to be equal both to the loss and potash in Vauquelin's; but the amount set down as loss in both cases is nearly equal, therefore the difference between the earthy and metallic products of the two analyses amounts to 13 per cent. being the proportion of potash as ascertained by Vauquelin. In order to obtain some clue by which to account for this difference, the methods of analysis pursued by these chemists have been compared and examined, but without obtaining much satisfaction.

Mr. Chenevix^b after finely pulverizing the feldspar, treated it with caustic potash in a silver crucible, and the whole was then brought to a limpid solution by muriatic acid. 1. The liquor was evaporated to dryness and the saline residue digested in a slight excess of muriatic acid, a white powder remained insoluble which was filix. 2. The muriatic liquor with the washings of the filix was then mixed with ammonia, and a copious precipitate was thus obtained. 3. This precipitate was then dissolved in muriatic acid, and afterwards boiled with an excess of potash by which the iron was deposited; and the addition of muriat of ammonia then threw down the alumine. 4. The ammoniacal liquor No. 2, was treated with carbonat of potash, by which carbonat of lime was procured. This method of analysis appears quite unexceptionable as far as the earthy and metallic contents are concerned, and, if carefully performed, there appears no reason why its results should not be considered as giving the true proportions and quantities of the earths and oxyd of iron contained in feldspar, proper allowance being first

^b Phil. Trans. for 1802 p. 333.

made for the inevitable errors to which the most accurate analysis is necessarily subject.

The method employed by Vauquelin was the following.^c Having fused the felspar with caustic potash, he dissolved the mass in dilute muriatic acid, and evaporated the whole to dryness: 1. the saline residue being drenched with water and filtered, the filex remained behind as a white insoluble powder. 2. The clear liquor being treated with ammonia produced a copious white precipitate. 3. This precipitate was digested in caustic potash and left behind the iron: muriatic acid was then added to saturation, and afterwards carbonat of potash threw down the alumine. 4. The liquor No. 2, gave no precipitate with carbonated potash or sulphuric acid, but oxalic acid occasioned a precipitate of oxalat of lime, which when calcined, was considered as carbonat of lime, whence the amount of the lime was estimated according to the usual proportions. The only exceptionable part of this analysis relates to the method of procuring the lime, and this on two accounts: in the first place, oxalic acid would not separate the whole of the lime from the liquor, which consisted of the muriats of lime, potash, and ammonia; and in the second place, the oxalat of lime which was precipitated ought by no means, after having undergone calcination, to be considered as carbonat of lime, but as lime in a semi-caustic state. It is further a singular circumstance and contrary to general experience, that carbonat of potash should have been unable to throw down the lime from the solution which was decomposable by oxalic acid. But even if we allow the utmost possible weight to these objections, and in consequence raise the amount of lime in Vauquelin's analysis to an equality with that of Chenevix's, there still remains a difference of 11 per cent. unaccounted for. That potash is really contained in the Siberian felspar appears also from a subsequent analysis by Vauquelin, in which he used caustic soda as the primary solvent, and afterwards obtained crystals of alum by the addition of sulphuric acid. It is however worthy of notice that the account of Vauquelin's experiments is not written by this eminent chemist himself, but is contained in a paper read at the *Société philomathique* by Le Lievre, and in consequence is not in the most authentic form.

With regard to the opposite analyses of adularia by the above mentioned chemists, it is difficult to form any satisfactory opinion, as the details of Vauquelin's analysis are not published.

It may however be remarked that in the amount of filex they exactly correspond, and that the proportion of alumine as determined by Vauquelin, approaches much nearer to the statement of Chenevix than in the former instance. The chief difference is the proportion of lime, but if, as is probable, the same method was used by Vauquelin on this occasion as was practised by him on the former one, it may be suspected that Mr. Chenevix's estimate approaches nearer to the truth. The water of crystallization amounting to 1.75 according to Chenevix, is wholly neglected by Vauquelin; and it is obvious that the proportion of potash as given by this chemist is from mere estimation, and is reckoned at 14. because just so much was wanted to complete the original 100 parts that he operated on. The iron obtained by Chenevix is perhaps only a casual ingredient of adularia: so that making the requisite allowances for each analysis, the quantity of potash can hardly be estimated at more than 6 per cent. It is however greatly to be wished that Klaproth or Hatchett would undertake anew the full analysis of this important mineral in all its varieties and subspecies.

Some further interesting particulars respecting felspar are contained in a memoir by M. Gerhard.^d Common felspar when heated to incandescence loses 1 per cent. (probably water). After being calcined it is readily acted on by sulphuric acid, and the product is a little selenite and much alum; the filex remaining unaltered by the acid. From an analysis conducted in this manner M. Gerhard states the constituent parts of felspar at

Silex	-	64.
Lime	-	6
Alumine	-	30
		100

Here it is worthy of remark that the presence of potash in this mineral is fully ascertained by the copious production of alum when it is treated after calcination with sulphuric acid, and this is the less liable to suspicion as the memoir was published long before the necessity of potash to the crystallization of alum was suspected; in consequence of which we find in Mr. G's analysis no mention of potash, and perhaps it is somewhat in favour of the reduction which we have made in the proportion of alkali as given by Vauquelin, that this reduced proportion, viz. 6 per cent. added to the quan-

^c Journ. des Mines, No. 49. p. 24.

^d Nouveaux Memoires de l'Acad. Roy. de Berlin, for 1783. p. 119.

tity of alumine found in common felspar by Chenevix, viz. 24 *per cent.* exactly corresponds with the amount of alumine as stated by Gerhard. In the proportion of flint he also agrees precisely with Chenevix, and in the quantity of lime differs only in the ratio of 6.25 to 6.

Common felspar inclosed in a crucible and exposed to a full melting heat, is converted to a milk-white semi-transparent mass resembling quartz. The addition of flint diminishes its fusibility and renders the mass more opaque. Four parts of felspar and one of chalk form a clear transparent glass of a slight yellowish green colour: but a much more beautiful glass may be obtained by calcining separately one part of sand, four of felspar, and two of chalk, and then fusing them together; this glass is however harder and more difficult to anneal than common glass, and the metallic oxyds only communicate to it dull muddy tinges of red and brown, except cobalt, which gives it a purer blue than common glass is capable of acquiring.

FERMENTATION (*Vinous*) *die Weinichte Gährung.* Germ.

The important process whereby saccharine solutions are converted into intoxicating liquors, capable of yielding alcohol by distillation, is one of the most complicated in chemistry, and the exact cause of this change is still but very imperfectly known. We shall therefore content ourselves in this place with noticing the principal requisites to fermentation, the circumstances that occur during the process, and the essential product, reserving to the articles *SPIRITS distilled*, *MALT-LIQUORS*, and *WINE*, some further particulars concerning these processes.

The only substances which we know to be unquestionably requisite to form a fermentable liquor are *Sugar* and *Water*. No vegetable juice will ferment that is not sensibly sweet, or from which a portion of sugar may not be extracted by chemical means; the strength of vinous liquors is (other things being the same) in direct proportion to the quantity of sugar contained before fermentation; the addition of sugar to the weakly fermentable juices will enable them to produce a strong full-bodied liquor, and the very essence of this process is the disappearance of sugar and the consequent production of alcohol.

With regard to the *water* it does not appear how far this is an active ingredient in vinous fermentation, but it is fully ascertained that a certain degree of dilution is necessary to this process; this degree exists naturally in the juice of grapes, the saccharine sap of many trees,

and other liquors spontaneously fermentable, and if these very liquors be deprived merely of great part of their water by gentle evaporation, they will not ferment till this is restored to them. On the other hand a saccharine juice may easily be too dilute, and then the fermentation is languid and imperfect.

But pure sugar and water alone will not ferment, and therefore some other substance is also requisite. Chemists have directed their attention largely to this point, but hitherto with little success, nor is it at all certain or rendered probable that this other substance must be any individual principle, or whether there are not several which will serve equally well towards the decomposition of the sugar. Must, or grape juice, contains, besides sugar and water, a quantity of vegetable acid, chiefly the tartareous, and one or more substances obscurely described under the name *extractive* or *mucilaginous*. Each of these is also requisite to its fermentation, for if either is abstracted the process will not take place. But the tartareous acid is composed of that which gives the acid property, together with hydrogen, carbon, and other ingredients also common to the mucilaginous extract. This latter can only be defined to be a substance highly soluble in water, giving it a certain degree of tenacity and density, remaining as a viscous jelly after slow evaporation to dryness, again soluble in water, most readily entering into spontaneous change at a moderate temperature, and giving by destructive distillation a number of gaseous products which indicate the presence of carbon, hydrogen, oxygen, and in very small portions, azot. But in the present state of chemical knowledge little progress is made towards a satisfactory explanation of this process by considering the *ultimate* analysis of the fermentable materials, and at present we must satisfy ourselves with their immediate composition.

It appears therefore from the example of grape juice, that at least four substances are requisite to fermentation, namely, sugar, water, an acid, and what (for want of clearer definition) may be termed extractive matter, and when these simply remain together for a short time in a moderately warm temperature they will be converted to a vinous liquor. The two latter substances we shall presently return to when the other requisites and circumstances of the process have been described.

A warm external temperature is also necessary to fermentation. This varies according to the natural fermentability of the materials and

their bulk. Thus grape-juice will readily begin to ferment at about 60°, and the process is strong and vehement at 70 or 80. The sugar cane juice is so excessively prone to fermentation, that in the climate of the West Indies the process would begin in from ten to fifteen minutes, and hence as fermentation is the destruction of sugar, it is necessary in the making of the sugar, to begin the operations on the cane-juice immediately after it is pressed from the plant. This operation begins with bringing it to a scalding heat, which immediately stops all tendency to fermentation. On the other hand no juice, however in itself fermentable, will ferment at a freezing temperature, so that all domestic processes of the kind are performed within doors or near a fire, and in the large way chilling must equally be avoided. But as fermentation is attended with the production of heat, the liquor within the vessel being always several degrees warmer than the outer air, large masses are of course less affected by the external cold and will ferment at a lower temperature.

The first signs of fermentation are a gentle intestine motion, the rising of small bubbles to the top of the liquor, and a whitish turbid appearance. This is soon followed by the collection of a froth or head, consisting of an infinite number of air-bubbles entangled in the liquor, which as the process advances rise slowly to a considerable height, forming a white dense permanent froth. A very large portion of the gas also escapes, which has always a strong agreeable penetrating vinous smell. The temperature of the liquor at the same time increases several degrees above the external air, and continues so during the whole of the process. Sooner or later these appearances gradually subside, the head of foam settles into a dense froth, and on turning it aside the liquor beneath appears much clearer, and nearly at rest, having deposited a copious sediment, and from being clammy and saccharine to the taste it is now vinous, and intoxicating, thinner and of less specific gravity.

The process however does not stop suddenly, but goes off very gradually, the liquor continuing to *work* or throw up foam, to clarify, to attenuate, to increase in intoxicating power, and more completely to lose all its sugar, which at last can now no longer be discerned by the taste, or detected by chemical analysis. The vinous liquor when complete, if of sufficient strength and well fermented, will now keep for an indefinite time in vessels secured from air,

and undergoes comparatively little further alteration except in becoming more perfectly limpid by the deposition of an additional quantity of sediment.

The nature of the gas of fermenting liquors has long been known to consist for the most part of carbonic acid, and therefore it will extinguish candles, destroy animal life, convert alkalies into alkaline carbonats, and the like. But it is not simply carbonic acid that is given off, for it has been found by Scheele to hold in solution a sensible portion of alcohol, and by Proust to contain a quantity of azot. Mr. Collier has also found^a that the gas contains all the materials requisite for vinous fermentation. For this, he passed the whole gas from a ninety gallon fermenting tun through a cask of water, and divided the water thus impregnated into three parts, the first of which was immediately distilled and gave a small quantity of spirit, to the second was added some yeast by which a new fermentation was excited and the subsequent product of distilled spirit was almost doubled, and the third being suffered to remain longer produced some vinegar.

The attenuation of liquors by fermentation or the diminution of their specific gravity, is very striking. This is commonly seen by the hydrometer, which swims much deeper in fermented liquor than in the same materials before fermentation. Most of this attenuation is doubtless owing both to the destruction of the sugar, which dissolved in water adds to its density, and to the consequent production of alcohol, which on the contrary by mixture with water lessens its density. The extract or mucilage also appears to be in some degree destroyed by fermentation, for the gelatinous consistence of thick liquors is much lessened thereby, though this quality as far as it depends on mucilaginous extract is not so completely lost as the saccharine material, many of the full-bodied ales for example, retaining much of their original clamminess and gelatinous density.

It has been doubted whether alcohol exists ready formed in vinous liquors, or whether it is not then in some intermediate state, and is brought to a perfect spirit by the boiling heat required for distillation. It is not easy to devise any unexceptionable mode of determining this question. Fabbroni argues in favour of alcohol being a *product* and not an *educt* from wine, that wine cannot be again formed by adding the distilled alcohol to the residue; and also that if a small portion of alcohol is added to wine, it

^a Manch. Mem. vol. 5.

may be separated again almost entirely by carbonate of potash (with which alcohol will not unite), but this salt will not separate any alcohol from wine in its natural state. This last fact however only shews that the union of the alcoholic with the other part of the wine is too strong to be broken by simple affinity without the assistance of heat; and as to the former, it is highly probable that the boiling heat operates some change on the other constituents of wine, the effect of which can never be done away by the mere return of the spirit which has been driven off. This opinion therefore though by no means improbable, wants further confirmation.

Alcohol is not immediately formed in fermenting liquors, as it does not appear till the fermentation is compleat, for the liquor distilled in the early stage of the process will not yield a drop of spirit.

The external air seems to have no chemical effect whatever in the process of vinous fermentation, as it may be conducted full as well in close as in open vessels, always allowing room however for the great expansion of the materials and the vast production of gas. Mr. Collier has also found by direct experiment that more spirit is produced by close than by open fermentation. In three separate experiments, in each of which equal quantities of wort and yeast were fermented under circumstances precisely similar, with the single exception that in one the vessel was open and in the other it was closed (having no exit but through a tube dipping in water) he found that on distilling each fermented liquor and obtaining the same quantity of spirit from each, that belonging to the close-fermenting vessels was constantly of a less specific gravity, and consequently contained more alcohol than the other. Where the spirit from the open vessel was 74 degrees below proof, that from the closed vessel was 56: where the former was 83, the latter was 65; and where 103, the other was 93.

The theory of vinous fermentation is still involved in extreme difficulty, on account of the very compound nature of all the substances employed in it, and their great tendency to decomposition in a variety of methods.

The results of the experiments of Lavoisier should not pass unnoticed, though it is obvious that much too great simplicity is attempted in the explanation of a process which every circumstance shews to be very complicated. It is some advantage however that the action of the external air so necessary to be considered in most decompositions of vegetable matter may

here be entirely put out of the question. The simple point to which Lavoisier's experiments tend is (setting aside all other agents) to explain how sugar becomes converted into carbonic acid and alcohol, which after all, is the great phenomenon of vinous fermentation. The entire products of sugar, yeast, and water fermented in close vessels, are stated to be carbonic acid, alcohol, and water, chiefly, together with a small quantity of acetous acid and part of the materials undecomposed. We shall not enumerate the exact composition given by this eminent chemist of all the ingredients and products of fermentation, nor enlarge on the many sources of inaccuracy which may be pointed out, but the theory suggested by the author from these experiments is the following. Sugar is a compound of about 8 of hydrogen, 64 of oxygen, and 28 of carbon, and the process of fermentation effects a change merely in the arrangement of the constituent parts of the sugar, converting one portion into carbonic acid and the other into alcohol: and hence as the carbonic acid contains only carbon with a large proportion of oxygen, the portion which is left must contain all the hydrogen, now concentrated into a much smaller compass, part of the carbon, and only the small remaining portion of oxygen. Or in other words, by this new arrangement of the ingredients of the sugar, one portion (namely the carbonic acid) is totally deprived of hydrogen and overloaded with oxygen, and consequently the other portion (which is the alcohol) abounds in hydrogen and is deficient in oxygen. The carbon is nearly equally divided between the two products relatively to their quantity.

Perhaps no more plausible theory has yet been offered of the general phenomenon of vinous fermentation, though it is so extremely defective in essential parts, and even not corresponding with the alledged composition of alcohol given by the same chemist in another part of his enquiries, that it can only be regarded as an ingenious and happy conjecture.

The great question still remains for future enquirers to determine: what is it that causes sugar to ferment; for it has been proved that sugar will not of itself begin this spontaneous change into carbonic acid and alcohol, though when once begun, probably the process will go on without further assistance. It has been already mentioned that both extractive matter and an acid are present in every known instance of vinous fermentation, and for any thing that appears to the contrary, both of them are necessary, though the requisite quantity of each is

very small compared to the sugar; therefore the strength or body of the fermented liquor is in direct proportion to the quantity of sugar alone, (the fermentation having been complete) and there is strong reason to suppose that the extractive matter and the acid are only accessory ingredients but still essential, or those without which the vinous decomposition of sugar cannot be effected.

It has been supposed that it is the *vegeto-animal* extract as it has been called, which exists in the fermentible juices of vegetables that causes the first change in the sugar. The precise nature of this *vegeto-animal* matter is not very well known, it may be supposed to be similar to the gluten of wheat, but most intimately combined with the vegetable saccharine mucilage, and hence extremely susceptible of spontaneous change. The chief if not the only proof of its existence in many of these combinations is the production of a quantity of ammonia when decomposed by heat, which alkali is almost uniformly *formed* by the action of fire, and indicates in the recent vegetable the existence of azot. It may therefore be more properly termed the azotic than the *vegeto-animal* ingredient, and as mentioned under the article BREAD, it seems to be peculiarly requisite to the panary fermentation, and to perform the most important part in this process.

Some of the commonest fermenting materials such as wort of malt, or the infusion of the soluble part of barley rendered saccharine by previous decomposition, it is well known will hardly enter into fermentation without the addition of *yeast*, and hence chemists have sought in this substance for the principle which gives the first impulse to the fermentation of sugar. The analysis of *yeast*^b presents a vast variety of ingredients, the chief of which are the carbonic, acetic, and malic acids, mucilage, sugar, and *gluten*. Of these the latter is in the largest proportion, which would seem to give much weight to the opinion of the great share which the azotic ingredient has in inducing fermentation.

Yet Mr. Henry^c found by a series of very interesting experiments that malt infusion might be made to enter into complete fermentation simply by impregnating it with carbonic acid from chalk and sulphuric acid, and the liquor thus fermented gave a yeast, which made perfect bread, gave alcohol by distillation, and vinegar by further keeping. Undoubtedly the wort itself contained all the ingredients of yeast

since this substance was produced during the fermentation, but the experiment is decisive to prove that no addition of azotic extract is required to begin fermentation in materials naturally fermentible, though when once begun, the yeast as fast as it was produced must have assisted in the fermentation then going on.

The evidence for the necessity of an acid to begin fermentation is therefore more decisive, but it still is doubtful what particular acid is required, or whether several will answer the purpose.

In Mr. Henry's experiments the acid was the carbonic, and from the arrangement of the apparatus probably a small portion of the sulphuric was also carried in along with it. But in grape juice no evidence can be given of the existence of the carbonic acid ready formed, though the tartaric, and malic, and other vegetable acids contain within themselves the two ingredients of carbonic acid, and it is well known that they are chiefly and ultimately resolvable into the carbonic. Yeast will even induce fermentation after it is pressed and dried into solid cakes, (a practice not uncommon as it will keep a great length of time in this form) but after this operation it can hardly contain an atom of carbonic acid ready formed, though with abundant tendency to produce it by the first mutual action of its other constituent parts.

Many interesting enquiries therefore remain to be carried on, before we can have a full and satisfactory theory of this most important process of vinous fermentation.

FERMENTATION, (*Acetous*). See ACETOUS ACID and VINEGAR.

FERMENTATION (*Putrid*). See PUTREFACTION.

FERNAMBOUC WOOD. See BRAZIL WOOD.

FERRILITE. See BASALT.

FEUERSTEIN. See FLINT.

FIBRE OF PLANTS. Almost all plants contain a fibrous matter, which is distinguished by its comparative insolubility in all chemical agents, indestructibility by spontaneous change, and by a certain toughness and elasticity produced by the strong intertexture of minute fibres. These fibres are sometimes highly flexible and firm, as the stringy stalk of the hemp plant, the aloe, the bark of the birch, and other trees that afford all the varieties of matting; with greater hardness and brittleness they exist in the cane, but still highly flexible and elastic; and with still greater density and diminished flexibility

^b Westrumb. Thomson's Chem. Vol. 4.

^c Manchester. Mem. Vol. 1.

they form the ligneous fibre or wood of the larger trees. The chemical analysis of vegetable fibre, which presents a greater proportion of carbon and earthy matter than any other vegetable substance will be described under the article Wood.

FIBRIN (Animal), MUSCULAR FIBRE or FLESH.

The muscle or flesh of animals, a substance equally important in the study of physiology as of animal chemistry, is composed of an infinite number of oblong or cylindrical, soft, nearly inelastic, semitransparent, generally somewhat red fibres, which examined microscopically are seen to subdivide, as far as the power of glasses will carry the eye, into bundles of fibrils parallel to each other, and bound together by minute cellular web of obviously a different nature. The circumstance which in a physiological point of view peculiarly distinguishes muscular fibre from every substance in nature is its disposition, when living, to contract in length on the application of stimuli, and to return immediately to a state of relaxation, an inherent power totally independent of any known mechanical laws of motion, and a grand phenomenon of animal life.

When fibre is chemically examined it must be remembered that the living muscle, besides being intersected to extreme minuteness with cellular web, is penetrated by arteries, veins, nervous fibrils, and lymphatics, all of which, with their contents, must be more or less mingled with the proper fibre, and therefore the chemical analysis of pure fibre cannot be precisely ascertained. However, maceration with water and mechanical pressure will remove much of this extraneous matter, and in this state we must at present consider it.

Fibrin, it may be premised, has so close a resemblance with the gluten or coagulum of BLOOD, that in a chemical point of view these substances are nearly identical.

When a portion of muscle cut into thin shreds is macerated in cold water for several hours, the water becomes red by the extraction of the blood and extraneous parts combined with the animal fibre, which last gradually becomes whiter and cleaner. This maceration should be assisted by frequent pressure, and by often changing the water it may be continued several days without putrescency in the fibre itself. If the flesh is then boiled long in water some more animal fluids are extracted, chiefly gelatin, together with coagulated flocculi

of albumen as Fourcroy has observed, and some drops of oil. When the soluble parts of fibre are wanted for domestic purposes, as for broths, soups, &c. the previous maceration in cold water is omitted. The fibre after the action of cold and hot water is exhausted, remains a grey white insipid stringy substance, which rather hardens by the further continuance in hot water, and when dried slowly in a warm air becomes semitransparent like horn and very brittle. This is fibrin in the purest state in which it can be procured.

Fibrin thus prepared is totally insoluble in water. It dissolves readily in most of the acids, but with the dilute nitric it gives out a large portion of azotic gas of great purity. A stronger nitric acid produces a more complicated effect, and, as Berthollet has observed in his valuable Memoir on Animal Matters, converts part of it into a kind of suetty fat which collects on the surface, whilst another portion is changed by means of the nitric acid into the oxalic, which therefore is always found in the remaining liquor.

Fibre added to the fixed alkalies gives off some ammonia, and is reduced to a kind of soap by union with the alkali.

Mr. Hatchett's valuable experiments^a on this substance throw great light on the constitution of muscular fibre, and point out a most striking resemblance to condensed albumen in a variety of particulars before unnoticed. They are chiefly the following. Muscular fibre (previously exhausted by long maceration in cold and hot water of every thing soluble in that fluid) was steeped for a fortnight in nitric acid diluted with three parts of water. The acid acquired a yellow tinge and had acquired all the properties of the nitric solution of *albumen*. The chief part of the fibre thus thoroughly penetrated by the acid was then put into boiling water, in which it dissolved and gave a gelatinous mass by evaporation, which, when redissolved in water, was precipitated by infusion of tan and by nitro-muriat of tin, in the precise manner of all the common albuminous solutions. The fibre after steeping in the acid was chiefly dissolved in ammonia, forming a brown orange solution. With potash ammonia was extricated, and it formed a soap like the albuminous soaps. The residue left undissolved after the action of ammonia consisted chiefly of fat. But when the washed fibre was treated with *boiling* nitric acid, the solution still more closely resembled that of albumen in nitric acid, but with this

^a Phil. Trans. vol. 90.

additional circumstance, that on supersaturation with ammonia a copious white precipitate fell down, which consisted of the phosphat and oxalat of lime, of which the former preexisted in the fibre, and the oxalic acid of the latter was *formed* by the action of the nitric acid on some portion, probably the gelatinous, of the fibre, and then united with the carbonat of lime which is also present.

The solution if made by *boiling* nitric acid also contains a notable excess of oxalic acid as well as oxalat of lime, but this acid is not found in any state when only *cold* nitric acid has been used, and hence the oxalic acid is obviously a product and is not to be considered as a constituent of muscular fibre.

The liquor or broth of fibre boiled in water contains, besides gelatin and other animal juices, a quantity of phosphat of soda and even phosphat of lime, which is almost entirely extracted from the fibre by long boiling.

Lime therefore is found in muscular fibre in two states, as a phosphat which is chiefly separable by long boiling, and in some other state in which it is not extracted by water but remains ready to combine with the oxalic acid as soon as formed, for this acid will not decompose the phosphat. This other state therefore is probably the carbonat, and the quantity of lime in this combination is sufficient to form 17 grains of the dry oxalat from 200 grains of the muscle previously exhausted by water and dried, and then dissolved in boiling nitric acid and precipitated by ammonia.

Much difference appears in the quantity of earthy salts in muscular fibre in proportion to the age of the animal. Thus Mr. Hatchett found that though beef contained both phosphat and carbonat of lime, veal gave hardly any indications of the latter and a much smaller quantity of the phosphat, a circumstance of some importance in physiology.

The analysis by fire shewed the following very notable difference between the three great constituents of the soft parts of animals, namely gelatin, albumen, and fibrin, in the proportion both of carbon and of earthy residue.

Five hundred grains of isinglass (the purest specimen of gelatin that can be taken) distilled with a strong heat in close vessels left 56 grains of residue, of which 54.5 were lost by open calcination and therefore were carbon, and the residue, amounting to 1.5, appeared to be phosphat of soda with a trace of phosphat of lime.

Five hundred grains of dry albumen treated in the same way gave 63.25 grains of carbon

and 11.25 of residuum, chiefly soda, rendered caustic by the heat, together with phosphat of soda and a very small portion of phosphat of lime.

Five hundred grains of dry prepared muscle of beef gave 82.4 of carbon and 25.6 of residue, the greatest part of which was carbonat of lime mixed with some pure lime and a little of the phosphat. But still more earthy salt is contained in muscular fibre than appears in this estimate, as the muscular fibre was previously exhausted of every thing soluble in boiling water, under which, as already mentioned, is to be included almost all its natural content of phosphat of lime.

The general inference from these experiments and others mentioned under the article ALBUMEN, is that (setting aside the saline, earthy, and what may be considered as accessory ingredients of muscular fibre derived from its intricate organization) the principal constituent is a substance which from the effect of the leading chemical reagents may be inferred to be nearly identical with inspissated albumen, and this appears to be the primary substance of the organization of many if not most of the soft parts of the body in which the most important functions of life reside.

A few miscellaneous circumstances may be added concerning muscular fibre. When thoroughly washed and freed from all that water can extract, it does not readily putrefy, but in its natural state it soon undergoes this change, the texture becomes flabby and loose, the colour pale, and the smell excessively fetid. The flesh of young animals (other things being the same) more readily putrefies than of old ones. When immersed in running water, or buried under ground under particular circumstances, it changes to that singular spermaceti-like matter which has been termed ADIPOCIRE. When muscular flesh is slowly and thoroughly dried and kept in a dry air, it will remain long without undergoing any change. Alcohol extracts the colour from muscle, hardens its texture and effectually preserves it from further change. In general almost all the antiseptics are more efficacious in preserving fibre from putrefaction than any other of the soft parts of the body.

Of the volatile products of the distillation of muscular fibre ammonia is the most important, and indicates the existence of much azot in the fibre itself. An acid is also given out, which is acrid, not crystallizable, and has the peculiar smell of roast meat. It was considered by Berthollet as an undescribed acid, and called by

him the *zoonic*, but it seems now generally allowed that it consists chiefly of the acetous acid fouled and altered by some of the animal substances rendered empyreumatic by the heat used to procure it.

FILTRATION is one of the daily operations in chemistry, apparently simple and trivial, but concerning which a few useful particulars may be mentioned. (*See the Appendix, article Filter*).

FISH SOAP is a kind of soap lately attempted to be introduced in manufacture, made by dissolving refuse fish of all kinds in caustic alkali. (*See SOAP*.)

FIRE. See CALORIC.

FIRE DAMP is that inflammable gas generated in many mines, particularly coal pits, which often produces most dreadful explosions when accidentally fired by the workmen. It is only to be prevented by thorough ventilation.

FLESH. See FIBRIN.

FLINT.^a *Feuerstein*. Wern. *Pierre a fusil*. Broch. *Quartz-agathe pyromaque*. Haüy.

The colour of this mineral is smoky-grey of different shades, passing into greyish-black and almost perfect black, or yellowish-grey passing into yellowish-white, wine and ochre yellow; it also occurs bluish-grey, yellowish and reddish-brown. Two or more colours are often found in the same specimen forming points, spots, clouds, or stripes. It generally also exhibits opaque white spots. It occurs in mass, disseminated, in angular grains and fragments, in globular and tubercular masses, or carious, and amorphous, sometimes also in pseudo-crystals either pyramidal or prismatic moulded on calcareous spar. It also constitutes the substance of various petrifications as echinites and coralloids. Its external lustre is casual, internally it is glimmering. Its fracture is perfectly conchoidal: it breaks into indeterminately angular and very sharp-edged fragments. It sometimes though rarely occurs in lamellar distinct concretions. It is translucent, varying in degree according to the depth of colour, the very light-grey varieties being semi-transparent. Its hardness is a little greater than that of quartz, it is easily frangible in any direction. Sp. gr. 2.58 to 2.59.

When exposed to the blow-pipe it becomes of an opaque-white, but is wholly infusible without addition. By being heated red hot in a distillatory apparatus it yields from one to two per cent. of a somewhat empyreumatic water and a little carbonic acid. If projected on fused nitre, it gives out a few sparks accompanied by a slight detonation. It has been

analysed by Klaproth^b and Vauquelin,^c with the following results.

	Klap.	Vauq.
Silex - - -	98.	97.
Lime - - -	0.5	0.
Alumine - -	0.25	1.
Oxyd of Iron	0.28	
Loss - - -	1.	2.
	100	100

The cloudy and opaque greyish specks which frequently occur in this mineral contain according to Vauquelin, from two to five per cent. of carbonated lime, and the white opaque crust with which those specimens are covered that are taken immediately out of chalk, consists according to the same able chemist of

Silex - - -	86.42
Oxyd of iron - -	1.23
Carbonated Lime	9.88
Loss - - -	2.47
	100 ..

Flint occurs sometimes though rarely in primitive rocks forming veins, but when belonging to this formation its fracture has a tendency to splintery, and is less easily frangible than common flint, and in fact appears to be a variety of hornstone passing into chalcedony. Common flint occurs in rounded pebbles constituting the greater part of the extensive beds of gravel which accompany the ranges of chalk-hills, but here it is evidently worn by attrition and disposed in a fortuitous irregular manner. It is only in the chalk-hills themselves that it appears in its native repository: here it is disposed in regular beds alternating with the chalk; and detached masses are often enveloped in the chalk itself. A bed of flint is never a continuous stratum, but is composed of irregular flattened nodules with tubercular or long projecting processes, each separated from the other by ochery chalk, yet the whole bed preserves its parallelism very exactly. Many nodules are hollow, and if the cavity communicates with the outside, are for the most part filled with chalk, but if there is no external aperture, the hollow is lined with minute pyramids of quartz or tubercles of chalcedony.

The formation of flint is a problem that has been discussed by the contending parties of Neptunists and Volcanists, but without coming to any satisfactory conclusion on either side:

^aBrochant, Jameſon, Kirwan.

^bAnalyt. Eff. I. p. 40.

^cJourn. des Mines No. 33. p. 702.

neither the infiltration of dissolved nor the injection of melted silice, at all accounting for the regular manner in which the beds of flint are disposed. Thus much is certain, that flints recently taken out of the quarry (not out of gravel beds) contain a much larger proportion of water than is indicated by their analysis, which probably was performed on long-kept specimens, since at every fracture the whole surface is covered over with minute drops of dew, which give a very sensible moisture to the finger when rubbed over it. It also seems evident that the flints in chalk beds have formerly been in a soft state, because they are constantly found covered with a hard white coat, a line or more in thickness but not separated from the rest of the stone, which contains from 9 to 10 per cent. of lime.

Those flints which burn to a pure white colour are employed in the finer kinds of pottery. The light-coloured flints are made into gun-flints, for which they are admirably qualified by the plenty and vivacity of the sparks which they yield on collision with steel, and from the ease with which they are manufactured on account of their natural tendency to break into wedge-shaped fragments. Flint is also an excellent material in building; the irregularity of its surface affords numerous points of contact for the cement, and it appears unalterable under every vicissitude of weather. Numerous beautiful specimens of flint buildings occur in the counties of Essex, Suffolk, and Norfolk.

FLOETZ. See Rocks.

FLOWERS. *Blumen*. Germ.

The old chemists were accustomed to denote by this name several substances both metallic and otherwise, which were procured by sublimation and were in the form of slightly cohering powder or spicular crystals. Thus we find mention made of flowers of antimony, arsenic, zinc and bismuth, which are the sublimed oxyds of these metals either pure or combined with a little sulphur or muriatic acid; also of flowers of sulphur, of benzoin and sal ammoniac. The term is at present almost entirely fallen into disuse.

FLUOR^a. *Chaux fluatée*, Haüy.

This species is divided into the two following subspecies.

I. FLUOR SPAR; *Fluss-spath*, Wern. *Spath fluor*, Broch. *Blue John*, of the Derbyshire miners.

The colours exhibited by this mineral are very various; it is pearl or smoky-grey, yellow-

ish-brown passing into brownish-black; or reddish-white passing into rose colour, (the false ruby of some authors); or violet blue (false amethyst) passing into smalt, and sky-blue (false sapphire) and bluish-black; or greenish-white passing into apple-green, grass and emerald-green (false emerald, (*prime d'éméraude*)); or wax and honey-yellow (false topaz). In the crystallized varieties the colours are for the most part uniform, but the massive variety displays several colours arranged in dots, clouds, and parallel waving or angular veins like the fortification agate. It occurs in mass, disseminated, and crystallized. Its primitive figure is a regular octohedron composed of tetrahedral molecules: it also exhibits the following varieties.

1. The octohedron, the summits of which terminate in lines instead of points.

2. The cube.

3. The rhomboidal dodecahedron.

4. The octohedron, all the edges of which are replaced by secondary planes.

5. The cube modified in the same manner as the preceding variety. When this modification attains its limit the original faces of the cube disappear, and are each replaced by a very broad four-sided pyramid.

6. A solid exhibiting facets with four, six, and eight sides, and produced from a combination of the octohedron with var. 2 & 3.

7. An imperfect octohedron with convex faces giving the whole a spheroidal appearance. The crystals are either single or irregularly intermixed or accumulated upon one another forming rude prisms. Their size varies from very small to very large. The surface of the crystals is either smooth and shining or rough and glimmering: the surfaces of the octohedron are generally rough. Its internal lustre is brightly shining and vitreous, somewhat inclining to pearly. Its fracture is foliated in four directions; its fragments are for the most part tetrahedral. When in mass it is translucent; the crystals are generally transparent or semi-transparent. It occurs sometimes in granular, rarely in lamellar distinct concretions. Its hardness is superior to that of calcareous spar; it is brittle and easily frangible. Sp. gr. 3.1 to 3.2.

Fluor spar when exposed without addition to the action of the blowpipe, crackles and decrepitates with considerable violence, and at length melts down into a greyish-white enamel. When laid on hot charcoal it gives out a bluish or greenish phosphoric light, a similar light is also produced by rubbing together two pieces in the

^a Emmerling, Haüy, Brochant, Jameson.

dark. Certain varieties of fluor are more phosphorescent than others, but the most remarkable example of this phenomenon is a violet-coloured fluor found in Siberia, and sold in Europe in small pieces under the name of *chlorophane*: if this is laid on a hot coal it presently is observed to glow with a most beautiful phosphorescent light of an emerald colour; after each heating its violet colour is diminished, and when it is become nearly colourless its phosphorescence is exhausted.

If sulphuric acid is poured on very finely pulverized fluor spar, and a gentle heat is applied to the mixture, a peculiar gaseous acid is disengaged which has obtained the name of the Fluoric.

Fluor spar has hitherto been only analysed by Scheele, who states it be a compound of

Lime	- - -	57.
Fluoric acid	- -	16.
Water	- -	27
		100

Besides these which may be considered as the essential constituents of this mineral, the coloured varieties contain oxyd of iron and very often bitumen; this is particularly the case with the blue and black kinds; hence it is that blue fluor when laid for a time in warm ashes, acquires an orange or bright ochre colour from the evaporation and decomposition of its bitumen.

Fluor spar forms veins in primitive mountains accompanied by tin ore, mica, apatit, and quartz, as in Cornwall, and at Zinnwald in Bohemia; it also occurs in argillaceous schistus accompanied by spathose iron ore, quartz, calcareous spar and heavy spar, in Cumberland and Durham; also in secondary limestone filled with organic remains, accompanied by galena, blende, calcareous, pearl, and heavy spars, quartz, clay, and solid bitumen, in Derbyshire. It is also met with in Aberdeenshire, in Brittany in France, Chamouni in Switzerland, in Saxony, Swabia and the Hartz, in Germany, and in Norway and Sweden.

Fluor was formerly and still continues to be used, as a very efficacious flux in the reduction of various metallic ores, whence it obtained its name: it is also the only substance from which fluoric acid is procured. The massive pieces when of sufficient size, solidity, and beauty, are wrought into various extremely ornamental objects such as vases, basons, obelisks, &c. This

manufacture is entirely confined to Derbyshire, no other part of the world affording fluor sufficiently compact for this purpose. The fluor that is manufactured, commonly called *Derbyshire spar*, is found only in one mine a little to the West of Castleton; it here occurs in veins and detached masses from three inches to a foot in thickness. The method of manufacturing it is as follows.

"When the fluor is intended to be worked into a vase or the like article, a piece is selected fit for the purpose, and if after minute examination it be found free from defects, it is carved with a mallet and chissel into a spherical form, and then fixed on a chock with an exceedingly strong cement. The chock is then screwed on the lathe, a slow motion is produced and water continually drops on the stone to keep the tool cold, which is at first applied with great care. This tool is a piece of the best steel, about two feet long and half an inch square; it is reduced to a point at each end, and tempered to suit the work. As the surface becomes smoother the tool is applied more boldly and the motion much quickened, till the piece of fluor be reduced to its intended form.

"The piece being thus formed and rendered smooth by the steel instruments, in order to render it fit to receive a polish, a coarse stone is applied with water so long as the smoothness is improved by these means, then finer grit-stone, pumice, &c. till the piece be sufficiently smooth to receive coarse emery, and afterwards fine emery. If with the latter it appear of a good shining gloss, then the finest putty is employed for a considerable length of time, till the polish be as bright as possible, which is known by throwing water on it. If the part thus watered appear higher polished than the rest the polishing is continued till water will not heighten the appearance.

"The advantage of a lathe worked by water is particularly conspicuous in forming delicate hollow vases, &c. for by the use of the foot-lathe the fluor was frequently broken, and its laminated texture at all times disturbed, but the use of the water-lathe by its steadiness prevents these inconveniences."

II. COMPACT FLUOR. *Dichter. fluss.* Wern. *Fluor compacte.* Broch.

Its colour is clear greenish-grey passing into verdegriis and greenish-white; it is also occasionally marked with yellowish and reddish-brown

spots. It occurs in mass. Externally it is dull or feebly glimmering; internally glimmering, with a vitreous lustre. Its fracture is even, approaching on the one hand to imperfect and flat conchoidal, and on the other to splintery. It breaks into indeterminately angular and sharp-edged fragments; it is translucent; considerably harder than the preceding sub-species; and easily frangible.

It occurs in veins with fluor spar at Stolberg in the Hartz, and in Derbyshire, but is very rare.

FLUORIC ACID. *Acide Fluorique.* Fr. *Flussspathsaure.* Germ.

In the Transactions of the Academy of Sciences at Berlin for 1768, is contained a memoir by Margraaf on fluor spar. This able chemist found that when the above mineral was distilled with sulphuric acid a volatile acid vapour was disengaged which deposited a white earth on coming into contact with water: he also remarked that the retort in which the distillation was carried on, was corroded and worn into holes by the process. Three years after, Scheele published a valuable essay on the same subject, in which he proved that fluor spar consisted of lime combined with a peculiar acid, many of the properties of which were investigated by him with great success. Priestley then took up the subject, confining his attention for the most part to the action of fluoric acid in the state of gas. Since the date of these last experiments but few additions have been made to our knowledge of this acid and its various combinations.

The distinguishing property of fluoric acid is that when dry and in the state of gas it readily combines with flex, and still retains its elastic form: hence arises the peculiar and almost insurmountable difficulty of obtaining this substance in a state of purity.

Fluoric acid is procured from fluor spar: for this purpose a quantity of the mineral being reduced to a *fine* powder is to be mixed in a thick glass retort with an equal weight of concentrated sulphuric acid: upon the application of a gentle heat the sulphuric acid will combine with the calcareous base of the spar, and fluoric acid gas will at the same time be liberated and may be received in the mercurial pneumatic apparatus in the usual way. If the heat applied to the retort is somewhat considerable, and the gas is rapidly produced, the retort will give way in the space of a minute or two being eaten into holes by the action of the acid; if the process is conducted cautiously and at as low a

temperature as possible the retort may be made to last a considerable while longer. The gas thus procured, while confined over mercury, is perfectly colourless and transparent; it has a pungent suffocating odour like muriatic acid, produces immediate death to animals which are immersed in it, extinguishes the flame of a candle after having previously tinged its flame of a green colour, and changes certain vegetable blues to red. Its specific gravity is considerably greater than that of atmospheric air, but has not yet been ascertained with any accuracy. If this gas is mixed with atmospheric air a white vapour similar to but more copious than that occasioned by the muriatic acid gas in the same circumstances is the result; this appearance is partly occasioned by the combination of the acid with the moisture of the air, but principally by the deposition of flex, which takes place at the same time. The earth is in like manner deposited if the gas is received in water, and this experiment according to the circumstances under which the acid is disengaged, exhibits a variety of singular and interesting appearances. As soon as a bubble of gas passes from the beak of the retort into the water it is immediately diminished in size from the absorption of a portion of the acid, and the whole would be taken up if the globule did not instantly become coated with the earth deposited by that part of the acid which is absorbed, for the earthy film being interposed between the gas and the water prevents any further combination till the bubble reaches the surface of the water, where it bursts. If this is performed in a jar full of water inverted over mercury, and care is taken to prevent the gas from being mixed with atmospheric air, the whole of the gas is absorbed, and the flex in proportion as it is deposited diffuses itself through the liquor, which thus at length acquires a gelatinous consistence: when in this state the greater part of the earth may be separated by putting the whole in a piece of linen and squeezing it. The acid liquor thus procured being again inverted over mercury, will absorb an additional quantity of gas, and by thus treating it three or four times successively, a strong fuming acid liquor may be obtained, consisting principally of fluoric acid and water, but still holding in solution a portion of flex and probably also of alkali, from the decomposition of the glass of the retort. If this saturated liquor is mixed with a few drops of solution of silver a slight precipitate of luna cornea takes place,^a and the fluoric acid is thus sepa-

^a Priestley's Experiments methodized II. p. 153.

rated from a small portion of muriatic acid, which, when prepared in the foregoing manner, it is always found to contain. From the liquor thus purified a considerable quantity of pure fluoric acid gas may be obtained by heating it almost to ebullition, in a retort, and receiving the product in mercury. This gas appears to consist merely of fluoric acid saturated with as much water as it can hold in an elastic state, and at a moderately cool temperature seems to have no action on glass. It combines readily with water without depositing any earth, and has an astringent acidulous taste. A candle immersed in it is extinguished without any previous change in the colour of the flame: it combines with ammoniacal gas forming a white cloud:^b it dissolves camphor, and is taken up in large quantity by oil of turpentine, to which it communicates an orange colour and a pungent acid odour. If kept for some time in a bottle of soft glass it acts upon it though slightly, on which account it is a useful precaution before putting the acid in, to line the bottle with a thin coating of a mixture of oil and wax.

It has been proposed by some chemists, as a method of obtaining pure liquid fluoric acid, to make use of a leaden retort and receiver; in which case the fluor spar being previously reduced to an exceedingly fine powder is to be mixed in the retort with an equal weight of strong sulphuric acid; the application of a gentle heat, not exceeding that of boiling water, will force into the receiver a large quantity of acid gas, where it combines to saturation with water, and thus produces liquid fluoric acid. In this process, provided the spar selected was free from quartz, there is indeed no deposition of filix, but a very notable proportion of lead is volatilized, and remains for the most part dissolved in the liquor, which, on this account, is by no means so pure as the acid produced by Dr. Priestley's method.

Fluoric acid has not yet been decomposed, its base therefore is wholly unknown, and it is only from analogy that chemists suppose it to contain oxygen. A remarkable difference between the fluoric and muriatic acids is that the latter is incapable of becoming oxygenated: it will neither unite with oxygen in the state of gas nor when digested with manganese. Fluoric acid combines with the alkalies and alkaline earths, with alumine and filix, and with the metallic oxyds; the metals in a reguline state appear to have no affinity for dry fluoric acid,

but when liquid it will dissolve iron, zinc, copper, and arsenic, hydrogen being at the same time disengaged. The order of its affinities is as follows, lime, barytes, strontian, magnesia, potash, soda, ammonia, alumine, and filix.

The only use to which fluoric acid has been applied is engraving on glass. It appears from Beckman that this was first practised by an artist of Nuremberg, in the year 1670, who prepared his etching liquor by digesting together nitrous acid and finely powdered fluor spar, for several hours on a warm sand-bath, and then using the clear liquor as aquafortis is employed by the copper-plate engravers. But the knowledge and application of this liquor was confined to a few German artists, till, after the discoveries of Scheele and Priestley, the fluoric acid in a purer state was used for the same purpose by various ingenious artists in England and France. Puymaurin found the liquid acid prepared in leaden vessels according to Scheele's process to answer very well for this purpose in warm weather, but by cold, its activity is so much impaired as to produce little effect even in three or four days. The gaseous acid however is much more efficacious, and being at the same time sufficiently manageable with proper care, merits the preference. To engrave on glass, select a piece of plate-glass of the requisite size, cover it with hard engraver's wax, and with a needle or other suitable instrument trace the intended design as in common etching, observing that every stroke passes quite through the wax to the surface of the glass; which may be ascertained by placing the plate on a sloping frame like a portable reading desk, in which situation the light will shine through wherever the wax is removed. When the etching is completed, lay the plate with the engraved side downwards on a frame, in a box lined with strong sheet lead or thick tin foil, and place on the bottom of the box a few leaden cups containing a mixture of one part of very finely pulverized fluor spar and two parts of sulphuric acid: then close the lid of the box, and place it on a stove, or in any other convenient situation where it may be exposed to as high a heat as it can bear without risking the melting of the wax: fluoric acid gas will be copiously disengaged, and in a short time (from one hour to three, according to circumstances), the plate will be found sufficiently corroded.

FLUATS.

The compound salts formed by the union of

^b Scheele's Ess. p. 28.

fluoric acid with the various salifiable bases are denominated fluats, in the new nomenclature. Our knowledge of this genus of salts is as yet very imperfect, both because few experiments have been made on the subject, and because the acid employed has never been pure, but always more or less combined with silicic acid, by which its effect in many cases is very materially modified. The fluats are all decomposable in the moist way by sulphuric acid, and at a red heat by phosphoric and probably boracic acid.

FLUAT OF POTASH.

Caustic potash even when melted with fluor-spar in the proportion of four parts of the former to one of the latter is incapable of attracting from the lime any portion of fluoric acid; but if a solution of carbonated potash is substituted for the pure alkali a decomposition is effected without much difficulty, fluat of potash, with excess of base being held in solution, and a precipitate of carbonated lime remaining at the bottom of the vessel. The liquor being evaporated yields a saline mass which remains unchanged in the air.^c Fluat of potash may also be prepared by adding pure potash to the liquid acid, and the result is a gelatinous uncrystallizable mass, almost tasteless, and deliquescent in the air: this particular combination has not been analyzed, but in all probability contains silicic acid. A fluat of potash, still more charged with earth, is obtained by adding to the gelatinous acid liquor produced by the preparation of fluoric acid in glass vessels some pure or carbonated potash: a precipitate is immediately thrown down, which when dry, separates into minute white grains. This substance has an acid taste, and is soluble in 150 parts of boiling water, from which it is again in part deposited as the liquor cools. When melted, the silicic acid and alkali run into a glass, and the acid is volatilized; it is not probable however that the whole of the acid is thus driven off except the experiment is performed in an earthen crucible. Lime water or muriatic acid being added to the solution of silicated fluat of potash, separates nearly the whole of the alkali and causes a precipitate of silicated fluat of lime: a similar effect is produced by sulphat of magnesia.

FLUAT OF SODA.

This salt may be prepared in the same manner as the preceding by substituting soda and carbonat of soda in the place of potash and its carbonat. Fluat of soda crystallizes in small rectangular figures: it has a bitter and somewhat styptic flavour; it is permanent in the air, is

little soluble in water, and may be obtained in crystals by spontaneous evaporation. It decrepitates when suddenly heated and then melts without losing its acid into a semi-transparent vitreous mass. Fluoric acid will take up both soda and silicic acid at the same time, and the result is a salt which as far as it has been examined is analogous to silicated fluat of potash.

FLUAT OF AMMONIA.

This salt may be obtained in a solid state by adding one part of finely-pulverized fluor-spar to two parts of sulphat of ammonia, and heating the mixture in a subliming apparatus; a little ammoniacal gas is first liberated and then the fluat of ammonia rises and by degrees forms a crust on the inside of the capital, sulphat of lime being left behind. The same salt may be procured by saturating common fluoric acid with caustic or carbonated ammonia: a gelatinous precipitate of silicic acid is first deposited, and the clear liquor by slow evaporation shoots into minute transparent crystals. These crystals when exposed to heat in close vessels are in part decomposed; ammonia is first given out and then there rises an acidulous fluat of ammonia. Liquid fluat of ammonia is decomposed at a very gentle heat by chalk, producing carbonat of ammonia and fluat of lime. Lime-water also produces a regenerated fluat of lime, and the same effect takes place with muriatic and nitric acid of lime. Sulphat of magnesia is also decomposed by this salt; fluat of magnesia being precipitated.

FLUAT OF LIME.

We have already amply treated of the native fluat of lime, or fluor spar, in the preceding article; it remains therefore only to mention the little that is known of this salt artificially prepared. The affinity of lime for fluoric acid is stronger than that of any other base for the same acid; hence it may be prepared by adding lime-water or a solution of any calcareous salt to any other of the fluats, except perhaps fluat of magnesia; but the purest regenerated fluor is prepared by adding together fluat of ammonia to nitric acid of lime; the fluat of lime falls to the bottom, and when properlyedulcorated is in all probability entirely pure. This salt appears to be insoluble in water, but is readily taken up by liquid fluoric acid. It is phosphorescent when laid on a hot iron as native fluor is, and in like manner loses this quality by being ignited. It is insipid, unalterable by exposure to the air, and at 51° Wedgw. melts into a colourless transparent glass. It is decomposable

^c Scheele's Ess. p. 13.

by sulphuric acid and in part by the muriatic and nitric, and by the carbonats of potash and soda and most of the phosphats.

FLUAT OF BARYTES.

All that is known of this salt may be related in a very few words. It is prepared by adding fluoric acid, or still better an alkaline fluat, to nitrat or muriat of barytes; fluat of barytes is precipitated in a pulverulent form. This earthy salt is sparingly soluble in water, and is decomposed by lime-water, and by sulphuric acid, the former attracting its acid and the latter its base.

FLUAT OF MAGNESIA.

Carbonat of magnesia being added to fluoric acid, the carbonic acid is given out with effervescence and the magnesia dissolves. When the liquor approaches nearly to saturation the greater part of the fluat of magnesia, mixed also in all probability with filex, falls down in a semi-gelatinous state. The supernatant liquor by gentle evaporation deposits small transparent hexagonal prisms terminated by trihedral pyramids. These crystals are scarcely at all soluble in water, but are somewhat more so in alcohol: they are not decomposed by heat, nor, according to Bergman, by any acid.

FLUAT OF ALUMINE.

Earth of alum is soluble in fluoric acid, and the compound by evaporation assumes a gelatinous consistence, but does not crystallize. It is sweet and astringent to the taste, and always contains an excess of acid. It is not however a simple fluat of alumine but contains besides, potash, and perhaps some filex. Fluoric acid may in like manner be made to unite with alumine and soda, and this combination is capable of assuming a crystalline form. It has even been found native, and has already been described under its mineralogical appellation CRYOLITE.

FLUAT OF SILEX.

When fluoric acid is prepared by the usual process in glass vessels, it dissolves a portion both of the earth and alkali of which they are formed, and produces a gelatinous fluid which may be considered as an acidulous fluat of filex and alkali. If this liquor is kept for a considerable time in a glass vessel not entirely closed, it deposits small transparent shining crystals: these are partly soluble in the fixed alkalies, and give out fluoric acid by mere heat, or by any of the strong mineral acids. Not only glass but felspar, and probably all minerals that contain filex and potash, are very easily acted on by fluoric acid in a gaseous state, but the softest of the siliceous stones that contain no alkali, such as

opal, are attacked by it with much greater difficulty. The properties of pure fluat of filex have not yet been examined.

FLUOR VOLATILE ALKALI, a term for caustic liquid ammonia, now disused.

FLUX. *Fluss*, Germ.

A flux in chemistry means any substance which is added to another in order to assist its fusion when heat is applied. Thus alkali is a flux for flint, as, when mixed with it in due proportion and heated, it causes it to melt into the compound called glass.

The term flux is almost exclusively applied in chemistry to those substances, often saline mixtures, that are added to minerals or metallic ores to assist in the process of reduction. The general use of reducing fluxes, their advantages and inconveniences, are detailed in the description of the assay of the ores of COPPER, to which we shall refer the reader, and also to the methods of assay in the dry way of the ores of the other metals, particularly of IRON.

The White Flux is made simply by mixing equal parts of tartar or cream of tartar and nitre and deflagrating them in a clean crucible. The nitrous acid burns the carbonaceous part of the tartar, and the mixed alkalies of the nitre and tartar alone remain. This flux is therefore little else than a pure subcarbonat of potash.

The Crude Flux is the former mixture before deflagration.

The Black Flux is the most commonly employed of all the saline reducing fluxes. It is made by deflagrating in a large crucible a mixture of one part of nitre with two of tartar, and differs from the former in containing besides carbonat of potash a quantity of charcoal of the tartar, which there has not been nitre enough to consume. It therefore both assists in the fusion of ores by its alkaline ingredient and disoxygenates and reduces them to the metallic state by means of its carbon.

In making this flux, the materials, previously well mixed, should be thrown by small quantities into a red-hot crucible, and loosely covered after each projection, and as soon as the last portion is deflagrated it should be removed from the fire and kept in well-closed bottles to prevent the deliquescence of the alkali.

FORMIC ACID or ACID OF ANTS.

Ameisensaure, Germ.

The existence of an acid in these insects was proved by unequivocal signs long before its exact nature was understood. If an ant-hill, especially of the small red species be turned up or in any way disturbed so as to irritate the

insects, a very pungent acid vapour is perceived, which excites coughing, brings tears in the eyes, and in great intensity almost suffocates. If a piece of paper stained with litmus is held in this vapour it very speedily reddens as in any other acid vapour. Ants seem also constantly to exhale an acid whether irritated or not, so that the same changes produced on flowers and leaves by the known acids, take place when they are laid in the track of these insects, and it is conjectured that a part of the irritation caused by their bite is owing to the insertion of a portion of their native acid.

Margraaf^a was the first who procured the acid in substance by distillation of these insects, and the valuable researches of Arvidson,^b Bucholz, Deyeux,^c and Fourcroy and Vauquelin have thrown further light on the nature of this singular animal product.

Margraaf extracted the acid in the following way: a quantity of these insects collected in May and June was put into a large retort, water being poured upon them, the whole was distilled with a fire slowly increased to boiling. This process, continued till the product came over coloured, afforded an acid liquor on which a quantity of oil was floating, which became of a suetty consistence when cold. To separate all the acid, the residue in the retort was pressed and the acid liquor mixed with the acidulous water in the receiver, separated from the oil, and redistilled with care. The first portion, which was scarcely acid, was rejected, after which the distilled liquor was collected as long as it was free from empyreuma. This is the formic acid in considerable purity, but the dark and fouled residue in the retort still contains much of the acid, which may be separated by distillation in a water bath, if thought proper.

A more concentrated acid may be prepared in the way used by Arvidson. Collect a number of ants by laying a clean stick on an ant-hill repeatedly, and scraping them off into an alembic full of cold water. When this is quite full pour off the water (the use of which is to kill and wash the insects) and distil with a gentle heat till the liquor begins to flow foul and oily. Or the ants previously killed by water may be tied in a linen bag immersed in boiling water and repeatedly pressed till all the acid is extracted, which may then be purified by distillation. In any of these methods ants will yield nearly half their weight of an acid, which has a

very sharp sour acrid taste, and when purified by simple distillation is of about 1.0075 specific gravity. By repeated rectification it may be brought to about 1.0453.

A full enumeration of its properties and combinations is needless in this place, as it is found to be composed of the acetic acid, but mixed with a small portion of another acid, which appears to be the malic, holding in solution a certain and inseparable quantity of acrid volatile oily matter, or something of the kind, which gives the peculiar taste and smell that distinguish this acid from a simple mixture of the acids of which it appears to be composed.

A singular way of preparing the formiated alkalies in small quantity, is to lay cloths wetted in the alkali over the ant-hills and paths of these insects. After a time the alkali becomes saturated with the acid excretions of the animal, and the neutral salt thus formed may be extracted by lixiviation.

The analytical experiments of Fourcroy and Vauquelin^d on this acid may be added, as they prove its compound nature, and are important.

A quantity of ants was collected, cleaned and killed with cold water and bruised in a marble mortar, during which they exhaled a very sharp pungent odour like that of radical vinegar. They were then macerated for several days in alcohol, which became of a yellow colour. This alcoholic infusion was then distilled and gave an acid inflammable liquor. The residue in the retort was a very acid liquor mixed with a red extract, from which it was separated by the filter. The acid was then saturated with lime, and gave a brown thick nauseous liquor.

This formiat of lime had the following properties: mixed with sulphuric acid it exhaled a strong odour of vinegar: with nitrat of lead, gave a copious white precipitate; and with nitrat of silver, a yellowish precipitate. The mixture of formiat of lime and sulphuric acid being diluted and distilled yielded a clear, very acid, empyreumatic liquor, which now gave no precipitate with the salts of lead, and when combined with potash gave crystallized acetite of potash; with sulphuric acid gave radical vinegar; and with nitrat of mercury gave a flaky precipitate of acetite of mercury. The acid liquor therefore obtained from the formiat of lime by distillation with sulphuric acid, was fully ascertained to be the acetic acid mixed with some animal matter that gave the acid empyreuma.

But the formiat of lime also gave a copious

^a Mem. Acad. Berlin, 1749.

^b Bergman's Opuscula.

^c Journ. Phys.

^d Annales du Muséum Natl. or Phil. Mag. vol. 15.

precipitate with nitrat of lead, which pure acetite of lime will not do, and as this decomposition of the salts of lead was not found to be affected by the *distilled* acid above mentioned, it follows that this other acid is one that is fixed in a moderate heat, or else is so altered by the action of heat and sulphuric acid as no longer to retain its proper character. As it could not be examined with any convenience in the residue of the sulphuric acid and formiat of lime, on account of the embarrassment which the presence of sulphuric acid itself would produce, a large portion of the formiat of lime was mixed with nitrat of lead, and the white precipitate thus produced was separately collected and examined. It therefore consisted of oxyd of lead combined with the unknown acid, which, by further examination, was found to exhibit all the characters of the MALIC.

The quantity of acid contained in these insects is very surprizing, and far exceeds what is found in any other known part of the animal creation. It is obviously not a *product* of any chemical process used for the extraction, since the living insect abounds with acid, and produces the known effect of an acid on every thing that it touches.

FORMIATS are salts produced by the combination of the formic acid with alkaline, earthy, or metallic bases. From what has preceded, it will appear that the formiats are very intimate compounds of the acetite and malat of the base employed, together with a portion of acrid animal matter, the nature of which is little known.

FRAUENEIS. See GYPSUM.

FREEZING.

The theory and principal circumstances attending congelation having been detailed under the article CALORIC, we shall in this place merely relate some of the principal means employed for producing *artificial cold*, for experimental and economical purposes.

The preservation of snow or ice during the summer months is almost a necessary of life in hot countries, and an object of useful luxury in temperate climates. The construction of ice-houses is in general very simple, often indeed they consist of nothing more than deep caves hollowed out in the coldest side of mountains, and filled with ice or snow rammed down with much manual labour. Ice may generally be preserved during the summer, if the place selected be cool and thoroughly sheltered from the direct influence of the sun, if the ice be kept in considerable mass, with as few interstices

as possible, lined with straw, reeds, or any loose substance of the kind, which is a bad conductor of heat, and especially if it be kept dry both by avoiding external moisture and by giving an exit to the water formed by the slow liquefaction of the outer part of the mass. The common ice-houses are usually placed in the shadiest and coolest part of a wood, and consist of caves about eight or ten feet in depth, lined with masonry, unless cut out of a dry rock, finished at the bottom in the form of a sugar loaf, and the whole lined with a considerable thickness of thatch, straw, or reeds. The ice when thrown in is broken down as much as possible, that it may lie close, and when filling, water may be thrown on it, which by freezing will cement the whole into a hard solid mass penetrable only by the pickaxe. When filled it is covered very carefully with earth and thatch, leaving only a small entrance with a door at each end also very closely lined.

The snow-caves in Italy are no more than deep pits dug in the north side of a hill, lined with straw, and furnished with a small tap-hole at bottom to carry off the water formed by melting. The snow is rammed very hard, and if well laid up will keep during the whole summer.

But in tropical climates far distant from high mountains, as neither natural snow nor ice can be obtained, recourse is had to the cold generated by evaporation and the comparative coolness of the air a little before day-break, to manufacture ice in large quantities, and thus to supply a most grateful luxury at a moderate price. Ice is thus simply manufactured in the large way at Benares, Allahabad, and Calcutta, where natural ice has never been seen.^a On a large open plain an excavation is made about thirty feet square and two deep, on the bottom of which sugar-cane or maize stems are evenly strewed to the height of about eight inches. On this bed are set rows of small shallow unglazed earthen pans, so porous that when filled with water the outsidess are immediately covered with a thick dew oozing through them. Towards the dusk of the evening, the pans previously smeared with butter, are filled with soft water generally boiled, and let to remain there during the night. In the morning before sun-rise the ice-makers attend and collect from each pan a crust of ice more or less thick that adheres to the inner side, and is put into baskets and carried without loss of time to the common receptacle, which is a deep pit in a high dry situation, lined first with

^a Barker Phil. Trans. vol. lxxv. and Williams's ditto vol. lxxxiii.

straw and then with old blanketing, where it is beaten down and congeals into a solid mass. The crop of ice varies extremely, sometimes amounting to more than half the contents of the pan, at other times scarcely a pellicle. Clear and serene weather is the most favourable for its production whatever be the sensible heat of the atmosphere. The cold generated by the rapid evaporation round every part of the pan is the cause of this congelation. When used for the table, the ice is either added to the liquor to be cooled, or is put into a large vessel mixed with salt or nitre, and the sherbet, creams, and the like, intended to be frozen, are inclosed in thin silver vessels and immersed in the mixture. In this way ices are procured for the table, when the heat even in the shade is very commonly above 100°.

At the ice manufactory at Benares about 100,000 pans are reckoned to be exposed at a time, and the business of filling them at night and gathering the ice in the morning employs about 300 men, women, and children.

It is necessary that the cane-stalks be kept perfectly dry, if by accident any part becomes wetted, no ice will form in the pans above.

Mr. Williams found the temperature of the air on the cane-stalks never to be lower than 36°, and even plenty of ice would form in the pans when it was as high as 40°. What is remarkable, he found that ice was best formed with the gentlest winds, at which time a thermometer placed on the straw would always stand about 4 degrees lower than one fixed to a pole five feet higher, but in strong winds no such difference was observable, and then no ice was formed.

To compare the effect of the porosity of these vessels in lowering the temperature of water contained in them, Mr. W. took a new pot and one in which by long use the pores had been nearly stopped, and placed them in a hot westerly wind in the shade, where the heat of the air was 100°. On exposure for four hours the water in the old pot was 97, and that in the new pot was only 68°.

Many other instances of artificial cold produced by evaporation might be brought, many of which are detailed under the article CALORIC.

Another mode of producing cold is by freezing mixtures, or saline substances of various kinds, which during their liquefaction either by solution in water or in acids, absorb a vast quantity of caloric from all substances in contact with them. As a general rule it may be

observed that, all the compound salts produce a certain degree of cold during solution, and this effect is, *ceteris paribus*, the greater when the salts are naturally deliquescent and contain a large quantity of water of crystallization. The crystallized alkalies (that is the pure alkalies) also generate a most intense cold, as also do the acids when mixed with water already frozen.

It is somewhat doubtful whether or not the cold produced thus artificially equals the greatest degree of natural cold ever observed in any part of the world. These researches have been a good deal connected with the attempts to freeze mercury, partly on account of this fluid being the commonest thermometrical measure of heat, and partly because its real congelation was long a matter of doubt and incredulity, and though now a fact fully proved and not difficult to be effected, it requires an extreme intensity of cold for the purpose. The freezing point of mercury is found to be about — 39 or — 40 Fahr. and between this point and moderate summer heat are included all the primary diminutions of temperature produced by all the known freezing mixtures, or those that occur on the mixture of the freezing materials *not previously cooled*. But by two or three combined and successive operations, that is, by employing one freezing mixture to cool the materials for the next, and the latter perhaps for a third, a degree of concentrated cold has been generated which exceeds that of freezing mercury by at least 30 or 40 degrees, if the contraction in the alcohol thermometer (the only one of use in these cases) continues sufficiently uniform in its lowest degrees, which there is little reason to question. But as in some parts of Siberia and of the North of America, mercury has been known to freeze with great ease when simply exposed to the air for a short time, it is still uncertain whether artificial cold produced by chemists in ordinary atmospheric temperatures has ever equalled the natural cold of these climates, in which however man has existed.

Among the vast variety of freezing mixtures we may select some of the most important and the earliest of application, and particularly refer the reader to the numerous and interesting experiments of Mr. Walker on artificial cold,^b who seemed nearly to have exhausted the subject till the discovery by Lowitz of the astonishing frigorific effects of crystallized caustic potash, and the nearly equal powers of muriat of lime, which will be presently noticed.

^b Phil. Trans. Vol. lxxvii, lxxviii, lxxix, lxxxi, lxxxv, & xci.

The freezing mixtures may be with convenience classed (with Mr. Walker) into those in which saline substances are mixed with each other or with water, that is at a common tem-

perature, and those that require the use of water already congealed in the form of snow or powdered ice. These in a tabular form are the following:

<i>Crystallized Salts in Powder.</i>				<i>Liquor.</i>	<i>Reduction of therm. from 50° to</i>		
Muriated ammonia 5 :	and nitre 5	-	-	-	with water	16	- - + 10
Muriated ammonia 5 :	nitre 5 :	fulphated soda 8	-	-	ditto	16	- - + 4
Nitrated ammonia 1.	-	-	-	-	ditto	1	- - + 4
Nitrated ammonia 1 :	carbonated soda 1.	-	-	-	ditto	1	- - — 7
Sulphated soda 3.	-	-	-	-	dil: nitre a.	2	- - — 3
Sulphated soda 6 :	muriated ammonia 4 :	nitre 2.	-	-	ditto	4	- - — 10
Sulphated soda 6 :	nitrated ammonia 5.	-	-	-	ditto	4	- - — 14
Phosphated soda 9.	-	-	-	-	ditto	4	- - — 12
Phosphated soda 9 :	nitrated ammonia 6.	-	-	-	ditto	4	- - — 21
Sulphated soda 8 :	-	-	-	-	muriat. a.	5	- - 0
Sulphated soda 5 :	-	-	-	-	dil. fulph. a.	4	- - + 3

In the above mixtures the salts to produce their fullest effect should be recently crystallized, in fine powder, and containing as much water of crystallization as possible, but not damp. The mixture should be made in a thin metallic (or where the acids are used) a thin glass vessel, the salts, when of more than one kind, being successively added to the liquor in the order in which they stand and immediately stirred together. The cold continues during the solution of the salts and generally reaches its greatest intensity almost immediately on mixture, but with some ounces of the materials it continues very intense for a considerable time, and the effect may be advantageously prolonged by adding after a while a little more of the powdered salts. The figures in the table express the parts by *weight*, but where water is the liquor it may be *measured*, the common ounce measure being sufficiently accurate. The degree of dilution of the nitric acid is two parts by weight of the most concentrated acid diluted with one part of water, and the dilute sulphuric acid implies equal weights of the strong acid and water. These acids should be previously mixed with water that the heat on mixture may have escaped. All the above materials are taken at the common temperature of 50°. as this is as high as well-water ever rises to in the middle of summer, and therefore may generally be obtained by cooling the materials therein. But if a higher temperature be begun with, a greater proportion of the salt should be used. The cold produced by all these mixtures is found by inspecting the table to be very intense, but it must be remembered that it expresses the utmost effect, where the substance immersed is only the small bulb of a fine thermometer, and therefore

where the caloric transferred from the bulb itself to the freezing mixture is too small materially to counteract the cooling power.

But when these mixtures are used as the means of reducing the temperature of water or other substances immersed in them, the effect will of course fall greatly short of the degree here indicated, the refrigeration being in inverse proportion both to the bulk and the capacity for caloric of the substance immersed. The first of these mixtures, that is muriated ammonia, nitre, and water, will serve again any number of times, the salts being recoverable undecomposed by the simple evaporation of the water.

The above being the frigorific power of the several mixtures at an ordinary temperature, it is obvious that their effect will be augmented though in a decreasing ratio by cooling the materials of one mixture by previous immersion in another. In this way Mr. Walker was able to congeal mercury without using a particle of ice or snow by mixing nitro-sulphuric acid cooled to — 30 with sulphat of soda also cooled to — 14. This produced a cold of — 54 and was sufficient to freeze a small quantity of mercury immersed in it.

Another class of freezing mixtures and by far the most powerful, are those in which one of the materials is snow or powdered ice, and the other either an acid or an alkali or a neutral salt, or a mixture of some of these. The two that have been the longest known and are familiar to all chemists are common salt and snow, and nitrous acid and snow. Fahrenheit first ascertained that when equal parts of salt and snow are mixed together, a cold of 32 degrees below the water-freezing point of his thermometer is produced, which he was led to assume

as the zero of his thermometer. According to Mr. Walker a double proportion of snow produces a cold 5 degrees lower, and other salts

with snow have still greater powers as appears by the following table:

Muriat of soda 1.	-	-	-	-	with snow 2	produces a cold of	- 5
Muriat of soda 2 : muriat of ammonia 1.	-	-	-	-	ditto 5	- - - - -	- 12
Muriat of soda 10 : Muriat of ammonia 5 : nitre 5 :	-	-	-	-	ditto 24	- - - - -	- 18
Muriat of soda 5 : Nitrated ammonia 5.	-	-	-	-	ditto 12	- - - - -	- 25

and muriat of lime has a still greater effect as will presently be mentioned.

The above mixtures are taken at any common temperature.

In all these mixtures with snow the latter must be newly fallen, dry, light and uncompressed.

Nitrous acid and snow is another most powerful freezing mixture, the powers of which have long been known, and were resorted to in the first attempts to freeze mercury by artificial cold. The acid should be either the fuming acid *undiluted* or the pale concentrated acid diluted with one fifth of its weight of water. The necessity of this last was discovered by Mr. Cavendish, who found that this acid cooled to 32° , gave out a quantity of heat, and had its temperature raised by the first addition of snow, and when again cooled to 32° the thermometer again rose on adding more snow till about one fifth of the weight was added, after which no further interference with the frigorific effect took place.

Nitrous acid, either fuming and concentrated, or pale and properly diluted, when cooled to $+32^{\circ}$ added to fresh snow at the same temperature produces an instant cold of about -30° , and a very sudden liquefaction of the snow as if it were laid on a hot iron. The best proportions seem to be about one part of the acid to two parts, or rather less, of the snow. This is therefore not quite sufficient to freeze mercury in one operation, but if the acid and snow are previously cooled considerably, a small portion of this metal enclosed in a thin glass bulb will readily congeal. Thus if the acid and snow are each cooled as low as 0. or even a few degrees higher (which a mixture of salt and snow will readily effect) and then mixed, a cold of about -46 which will freeze mercury, will be generated. The same effect will take place according to Walker by adding snow at $+32^{\circ}$ to nitrous acid cooled to -29° ; or snow at $+25^{\circ}$ to nitrous acid at -20° ; or snow at $+20^{\circ}$ to nitrous acid at -12° . In these cases therefore the acid only need be cooled, the given temperatures of the snow occurring naturally every

winter, and sometimes, though rarely, a natural cold is felt in this country of a few degrees only above 0. at which time a mixture of nitrous acid and snow at that temperature will alone give a cold to freeze mercury. Ice rubbed to fine powder in a temperature below $+32^{\circ}$ (to prevent its getting damp by thawing) answers full as well as snow, and hence as ice may be procured at any time mercury may be hereby frozen by a succession of cooling operations even in the midst of summer.

Sulphuric acid, diluted with its own weight of water, and also strong muriatic acid added (each being at $+32^{\circ}$) to snow, produce a cold of very great intensity, though some degrees less than the nitric acid.

Two other most powerful frigorific mixtures have been discovered by Professor Lowitz, namely, caustic potash and snow, and muriat of lime and snow.

Potash in its common state is prepared by rendering the carbonat caustic by means of lime, and evaporating the solution of alkali first to dryness and then encreasing the heat to gentle fusion of the alkali, and cooling it in cylindrical moulds. The alkali thus prepared is seldom free from some lime, and also is totally deprived of all water of crystallization, and if in this state it is mixed with water a considerable quantity of heat is extricated, so as to make the mixture sensibly warm to the touch. But on the other hand if the alkali is dissolved by alcohol and then crystallized (in the manner mentioned under the article *Potash*) in this state Professor Lowitz found that on mixture with water much cold was generated, and with snow, a greater cold was produced than has hitherto been effected by any known combination. These experiments are curious. Twelve ounces of crystallized potash added to as much water, each at 59° Fahr. sunk the thermometer immediately to 33° . Four pounds of the alkali added to a pound of water at 33° gave a cold of 16° . With snow the effect was more striking. At the temperature of 19° , six ounces of potash with as much snow immediately sunk the thermometer to -42.5°

in which six ounces of mercury congealed in a few minutes. The same succeeded in a room whose heat was 59° . At a natural heat of 30° the same chemist made the following comparative experiments. Crystallized potash gave with snow a cold of -45 , fused potash deprived of water of crystallization, gave -15° : a very concentrated solution of potash gave -28 : caustic soda, -15 : liquid ammonia, only $+20^{\circ}$: dilute nitric acid, -10° : strong fuming nitrous acid, -23 : strong sulphuric acid, -10 : muriatic acid, 29 : strong acetic acid, -17 .

Reflecting on the superior frigorific powers of potash over the other salts, Professor Lowitz was induced to ascribe it chiefly to its great deliquescence, and hence made a trial of the other deliquescent salts, and particularly muriat of lime, and found it almost if not quite to equal the crystallized potash in this respect, and it has the great advantage of being very cheap, and of not injuring the skin of the hands by touching, which can hardly be avoided upon using the potash whatever precaution be taken.

Muriat of lime deserves particular attention as being the cheapest and most useful frigorific material hitherto known, and of extreme energy. The salt is often to be had at a very cheap rate, being a residue (hitherto useless) of the distillation of ammonia. To prepare it, the saturated solution should be evaporated to the consistence of a syrup when hot, and as it cools nearly the whole will congeal into a semi-transparent yellowish mass. This well dried should be reduced to fine powder in a dry cold air, and kept in a bottle very carefully closed. If these precautions are not taken, the salt very readily deliquesces, and is then unfit for frigorific purposes till again evaporated and crystallized. But as it is very readily prepared, it is better in most cases not to attempt the drying and powdering till a little before it is to be used; for when long kept even in a moderate temperature, some dampness is almost unavoidable.

The experiments of Professor Lowitz shew that considerable cold is produced by different proportions of this salt and water. The greatest diminution of temperature observed was 34 degrees, which was produced on adding 15 parts of muriat of lime to 10 parts of water.

When this salt and snow or powdered ice are mixed together, the cold produced is very intense, as will be seen by the following observations of the same chemist.

At a natural temperature of 26° six ounces of snow were mixed successively with the following

proportions of the muriat dry and in fine powder,

ounce.		
with 1	gave	-10° of cold
2	-	-24 .
3	-	-36
4	-	$-44\frac{1}{2}$
8	-	-55

No greater cold was produced with any higher proportion of the muriat, and therefore the best proportions are three of the muriat to two of snow. The whole quantity should be mixed together as speedily as possible, and the snow should be newly fallen, light, quite dry, and not consolidated by freezing on the ground, which would render it hard and lumpy.

These interesting experiments have been repeated in different countries and with uniform success,^d and as the congealing point of mercury is about -39 , this metal may readily be frozen at the common temperature of our frosts, that is, from about 20° to 32° , without any previous preparation, simply by mixing together the muriat of lime and snow or dry powdered ice. Messrs. Fourcroy and Vauquelin, on mixing 8 ounces of muriat of lime with 6 ounces of snow at a natural temperature of 18° , reduced the alcohol thermometer in a few seconds to -64° , and 8 ounces of mercury added to the mixture inclosed in a thin glass capsule, congealed in a very short time crystallizing in octohedrons.

The particulars of an interesting experiment made by Mr. Pepys^e and other chemists in London, deserve notice from the large quantity of mercury frozen, and the great intensity to which the cold was carried, and the proportions of ingredients employed for the purpose.

The temperature of the laboratory being 33° a mixture of 2 pounds of muriat of lime at 33 , and as much snow at 32° was made, and *fifty-six* pounds of mercury tied up in a strong bladder was first immersed in it. The mixture gave at first a cold of -42 . When it had risen to $+5$, by the contact of the mercury the latter was removed to another mixture in every respect similar to the former till it was cooled to -30 . While this was going on 5 pounds of muriat of lime were put in a japanned iron pail, standing in an earthen pan containing four pounds of muriat of lime and as much snow (and prevented from touching the bottom by means of corks) by which the muriat in the pail was cooled to -15 . As much snow at $+32^{\circ}$ was then added to the pail, which reduced the temperature therein to the extreme cold of -62 , and the mercury, previously cooled in the way

^d Ann. Chem. tom. 29.

^e Phil. Mag. vol. 3.

above mentioned to -30 , was immersed in the pail, and the whole covered with a cloth and suffered to remain. In an hour and forty minutes the whole mercury was found to be solidified, and the freezing mixture then had risen from -62 to -46 , that is, 16 degrees higher than when the mercury was put into it. The mercury was then cut and divided in various ways, bent with pincers, and shewed all the marks of a malleable metal before it returned to the liquid state.

It may be added, that if merely the congelation of mercury is wanted, the readiest way is to throw a little of the metal loose in a pretty large mass of the freezing materials, where it will congeal in a few minutes; but where this experiment is performed in a room with a number of persons standing round, the natural temperature will be so much raised that the operator can hardly depend on success, without previously cooling the muriat by a separate mixture of the same materials. It is also of great importance that the snow should remain without doors till the moment that it is wanted, and the whole of the muriat should be kept cold by immersing in snow or iced water the bottle that contains it. Great caution should be used in touching frozen mercury. It gives an immediate sensation like a wound from a rough-edged instrument, or as if the finger was squeezed in a vice, and the mere sensation can hardly be distinguished from the burn of red-hot iron. The part in contact immediately becomes quite white and numb, and there is no doubt that if it were to remain a very little time in contact with the frozen metal, a local gangrene like that of a common frost-bitten limb, would come on. It is removed by rubbing the part a little time with snow.

We may close this article with mentioning some miscellaneous facts observed on the effect of a cold of -40 or upwards on various bodies.

Red fuming nitric acid congeals into a thick mass like butter, losing all its suffocating odour.

The sulphuric and acetic acids become quite solid.

The strong muriatic acid has not hitherto been frozen by any cold.

Rectified oil of turpentine becomes thick and ropy at -50° .

Sulphuric ether first becomes milky, then crystallizes with the loss of all its odour.

Liquid ammonia congeals into a thick jelly like the liquor silicum.

None of the gasses have yet been reduced to a solid state by any intensity of cold.

FRENCH CHALK. See STEATITE.

FRENCH BERRY. See AVIGNON BERRY.

FRITT is a porous spongy mass arising from partial calcination of the materials of glass in the process of this manufacture. See GLASS.

FUEL. The materials used as fuel in chemical processes are chiefly coal, coke, and charcoal, each of which has its appropriate use, and concerning which some particulars will be mentioned under the article FURNACE. (See the Appendix.)

FULLERS EARTH. ^a *Walkererde*, Wern. *Terre a Foulon*, Broch.

The colour of this mineral is greenish-white, greenish-grey, olive and oil green; or light yellowish green, and yellowish grey passing into pale ochre yellow. Its colours are sometimes disposed in spots and stripes. It occurs only in mass; and is without lustre. Its fracture is uneven passing into large conchoidal and flaty, or fine grained earthy. It breaks into indeterminate blunt edged or flaty fragments. It is opaque, sufficiently soft to be scratched by the nail, and brittle. It takes a polish by friction, adheres very slightly to the tongue, and is unctuous to the touch. It is moderately heavy, but its specific gravity has not been accurately ascertained.

It does not become plastic with water, but when immersed in this fluid, especially when warm, it breaks down into a fine powder. It does not effervesce with acids: before the blowpipe it melts into a brown spongy scoria. The constituent parts of the Fuller's earth of Hampshire, according to an analysis by Bergman, are

Silex	-	-	-	51.8
Alumine	-	-	-	25.
Lime	-	-	-	3.3
Magnesia	-	-	-	0.7
Oxyd of iron	-	-	-	3.7
Water	-	-	-	15.5

100.0

There appear to be two distinct formations of Fullers' earth, or rather, two different minerals seem to be confounded under the same name. The Fullers' earth of Saxony belongs to the primitive rocks, being found under strata of flaty grüstein, and passing by degrees into this very mineral, hence it consists of the same materials either originally deposited in this loose

^a Emmerling, Brochant, Jamefon.

state or having acquired this consistence from decomposition. The English Fullers' earth on the other hand is always found in beds covered by and resting upon that peculiar and hitherto undescribed sand-stone formation which accompanies and serves as the foundation to chalk: its colour is yellowish grey with a very faint scarcely perceptible tinge of green. It is found in Hampshire, near Woburn in Bedfordshire, and at Nutfield in Surry; at this latter place it is often mixed with crystallized heavy spar (sulphated barytes) of a yellowish-grey passing into very high and clear wine colour.

Fullers' earth used formerly to be in high request among the English manufacturers for clearing woollen cloth from the oil and grease which it acquires during the process of manufacture, and its exportation was forbidden under the severest penalties: in consequence however of the general substitution of soap for this purpose it is now almost wholly disused.

FULMINATION. This term differs from detonation only in degree: they both imply a rapid decomposition accompanied by a loud noise either with or without flame; but in those substances which have obtained the name of fulminating, the explosion is louder than in those which are said to detonate.

FULMINATING GOLD. See **GOLD**.

FULMINATING MERCURY of Bayen.

of Howard.

See **MERCURY**.

FULMINATING POWDER.

This substance is thus prepared. Take three parts of nitre, two parts of purified pearlash (*Kali preparatum*, *Lond. Pharm.*) and one part of flowers of sulphur, mix the whole very accurately in an earthen mortar and place it on a tile or plate before the fire till it is perfectly dry: then transfer it while hot into a ground stoppered bottle, and it may be kept without injury for any length of time. In order to experience its effects pour from ten to forty grains into an iron ladle and place it over a slow fire: in a short time the powder becomes brown and acquires a pasty consistence, a blue lambent flame then appears on the surface, and an instant after the whole explodes with a stunning noise and a slight momentary flash. If the mass is removed from the fire as soon as it is fused, and kept in a dry well closed vial, it may at any

time be exploded by a spark, in which case it burns like gunpowder, but more rapidly and with a greater detonation, but this effect cannot be produced on the unmelted powder how accurately soever the ingredients of it are mingled together. When fulminating powder is in fusion, but not heated to the degree necessary to produce the blue flame, a particle of ignited charcoal thrown upon it will occasion immediately a remarkably loud explosion.^a

It appears that the ingredients of the powder above mentioned do not acquire their fulminating property till combined together by fusion; that is till the potash and sulphur form sulphuret of potash. Hence fulminating powder may also be made by mixing sulphuret of potash with nitre, instead of adding the sulphur and alkali separate.

The cause of detonation, that is, of the loud noise by which it is characterized, is not very well understood: it used to be attributed to the sudden formation and evolution of an elastic fluid, but it is remarkable that some of the most terribly detonating substances, as fulminating silver, produce a very small quantity of gas in proportion to the violence of their explosion, and when fired in the chamber of a pistol, propel a ball with a very trifling velocity. The projectile force of an explosive compound probably depends on the quantity and elasticity of the gas produced, as gunpowder is superior for this purpose to any known substance, and at the same time yields the largest proportion of gaseous fluids; while in the violence of its report an ounce of this substance inflamed in the open air, is greatly inferior to that produced by even two grains of fulminating silver. The sphere within which detonating bodies act, appears to diminish in proportion to the increased violence of their explosion, but in return, the force exerted by them within the sphere of their action appears to be proportionably augmented.

FULMINATING SILVER. See **SILVER**.

FUNNEL. } Articles of chemical apparatus: for an account of which see the Appendix.

FUSIBLE METAL. See **BISMUTH**.

FUSIBLE SALT OF URINE. See **PHOSPHAT of Soda and Ammonia**.

FUSTIC. For the use of this dyeing drug see the article **DYEING**, p. 377.

^a Higgins's Minutes, p. 318.

G

GADOLINITE. * The colour of this mineral is deep greenish-black. When pulverized it becomes of a greyish green. It occurs in mafs, in nodules, or coarsely diffeminated. Externally it is rifted and glimmering, and is often covered with a whitish coating; internally it is fhining with a vitreous luftre. Its fracture is compact conchoidal, paffing fometimes into flaty and uneven. It breaks into fharp edged indeterminately angular fragments. It is opaque, but in very thin fhivers is transparent at the edges. It does not give fire with fteel, though it is too hard to be fcratched by a common knife. Sp. gr. 4.23. It is attractable by the magnet, and when mixed with fluor fpar and fufed affords a metallic button, amounting to about 8 per cent. alfo attractable by the magnet. When ignited it becomes of a yellowifh brown colour, and exhibits a flaty texture, and lofes about 1 per cent. of its weight.

The above is Klaproth's defcription, and is taken from the fpecimens which he analyzed. The gadolinite defcribed by Haüy and Brochant, and analyzed by Vauquelin differs from the preceding in the following particulars.

Its colour is pure black paffing into brownifh-black; it is hard enough to fcratch quartz, though flightly. Sp. gr. 4.04. It decrepitates before the blowpipe, becomes of a reddifh-white colour, and lofes by ignition nearly 10 per cent.

This mineral has hitherto been found only in Sweden; at Ytterby in Roflagen, and Kimif in Finland, forming veins in a granitic rock. It was firft difcovered by Arrhenius, and defcribed in Crell's Chemical Annals by Geyer in 1788. It was analyzed by Gadolin in 1794, and was found to contain a new earth, which has been called from the place whence it is procured, Yttria. Ekeberg, Vauquelin, and Klaproth fucceffively confirmed the difcovery of Gadolin, though with fome modifications: laftly, Ekeberg made a new analyfis of this mineral, differing in many refpects from the former one.

Where the analyfes of a mineral by three fuch able chemifts as thefe juft mentioned are found to differ from each other very materially, it is an interefting employment, and one of fome importance to the credibility of chemical analyfis in general, to endeavour to afcertain the caufe of thefe difcrepancies, the reader therefore

will, we truft, excufe us for treating this fubject with fome minutenefs.

The firft analyfis of this mineral is that made by Profeflor Gadolin, by which he found its conftituent parts to be

Silex	- - - -	31
Alumine	- - - -	19
Oxyd of iron	- - - -	12
A new earth	- - - -	38
		100

This analyfis though very incorrect, deferves to be quoted, as it is the firft that was made of this mineral, and as it eftablifhes the claim of the Swedifh profeflor to the difcovery of the new earth, now called Yttria. It is unneceffary, however, to enter into particulars, as the difficulties of the analyfis will be better illuftrated by an examination of the later analyfes.

Mr. Ekeberg of Upfal was the next who undertook an enquiry into the conftituent parts of this mineral. For this purpofe, 1. The levigated foffil was digefted with muriatic acid till every thing was taken up except the filex; 2. The folution was precipitated by cauftic ammonia, and the precipitate while moift was boiled in cauftic potafh. 3. The alkaline folution was fupersaturated by nitric acid, and then the addition of carbonated ammonia threw down the *alumine*. 4. That portion of the precipitate, No. 2. which was infoluble in potafh was diffolved in fulphuric acid, and after being boiled down to drynefs was ignited till it acquired a brick-red colour from the decomposition of the fulphated iron: being then boiled with water it left behind an *oxyd of iron* which was furtheredulcorated on the filter. 5. The water of No. 4. being flowly evaporated, deposited cryftals of fulphated yttria, and thefe being again diffolved in water the addition of carbonated ammonia occafioned a depofition of *carbonat of yttria*, from which when well wafhed the pure earth was obtained by ignition. By this mode of proceeding Mr. E. obtained from 100 parts of gadolinite

Silex	- - - -	25.
Oxyd of iron	- - - -	18.
Alumine	- - - -	4.5
Yttria	- - - -	47.5
		95.0

* Klaproth, Haüy, Brochant, Jamefon.

M. Klaproth^b having undertaken the analysis of gadolinite, began by the following preliminary experiments. 1. 200 grains of this mineral finely pulverized were treated with muriatic acid, which dissolved the greatest part of it; the insoluble residue was 49 grs. of *silice*. 2. The muriatic solution being evaporated to dryness was digested with alcohol, by which it was totally dissolved. 3. To the alcoholic solution diluted with water was added caustic ammonia, by which the whole of the earth and metallic oxyd was precipitated, as the supernatant liquor when poured off was not affected by carbonat of potash, even when the two fluids were boiled together. 4. The precipitate No. 3. was dissolved in sulphuric acid, evaporated to dryness, and ignited for half an hour; being then boiled and washed in water 76 grs. of red oxyd of iron remained. 5. The watery liquor was colourless and sweet to the taste, on the addition of carbonated ammonia a white earth fell down which was redissolved by an excess of the precipitant. The clear solution being then heated in a retort to expel the excess of ammonia, a copious white precipitate was deposited which when strongly ignited acquired an isabella yellow colour, and weighed 80 grs. 6. The oxyd of iron No. 4. was divided into two equal portions; one half being mixed with linseed oil was heated in a covered crucible and became obedient to the magnet, but being a second time treated with sulphuric acid and ignited, yielded by lixiviation a fresh portion of sulphat of yttria. 7. The other half of the oxyd was digested with muriatic acid, and precipitated with caustic potash: a small portion of the precipitate was redissolved by an excess of alkali, and this being supersaturated by muriatic acid, precipitated by carbonat of potash and again dissolved in sulphuric acid, afforded a few crystals of alum.

Having ascertained these preliminary facts, the regular analysis of this mineral was conducted by M. Klaproth in the following manner. 1. Two hundred grains of pure gadolinite in selected pieces were ignited in a covered crucible: when cooled they displayed a stony texture, and were become friable; their colour was changed to light yellowish brown, and they had lost one grain of weight. 2. They were then finely pulverized and digested in nitro-muriatic acid till the whole had acquired a gelatinous consistence, and appeared to be de-

composed. It was now evaporated to a moderate dryness, and again digested with hot water slightly acidulated with muriatic acid: the insoluble part when washed and ignited weighed 42.5 grs. and was pure *silice*. 3. The muriatic solution being largely diluted with water was mixed with a little soda, and thus perfectly neutralized; succinate of soda was then added till no further precipitation took place. This precipitate weighed 62 grs. and was succinat of iron, which being first ignited in an open crucible, and then heated with a little linseed oil in a covered crucible afforded 35 grs. of *black oxyd of iron* attractable by the magnet. 4. The solution No. 3. being decomposed at a boiling temperature by carbonated soda produced a white precipitate, weighing 219 grs. after edulcoration and gentle drying, but when exposed to a strong red heat for half an hour, yielded 121.5 grs. of a pale grey earth. This earth consisted of *yttria*, mixed with a small portion of *alumine*, the amount of the latter of which was estimated in the following way. 5. A hundred grains of gadolinite being decomposed by nitro-muriatic acid in the manner just mentioned, and the *silice* being separated, the solution was precipitated with caustic ammonia; and the precipitate when washed was introduced while yet moist into a solution of caustic soda. After boiling for a time the liquor was poured off from the insoluble part, and being first neutralized by sulphuric acid carbonat of soda was mixed with it, and the whole was boiled. By this method a white precipitate was obtained weighing 6 grs. after ignition. This being again dissolved in muriatic acid, and saturated to excess with carbonat of ammonia, left a very small portion undissolved: this insoluble portion being transferred to sulphuric acid was taken up by it, and yielded with a little potash about 5 grs. of alum, indicating half a grain of *alumine*, or one grain in 200 grs. of the entire mineral. Therefore 100 parts of gadolinite contain

<i>Silice</i>	- - -	21.25
Oxyd of iron	- - -	17.5
<i>Yttria</i>	- - -	60.25
<i>Alumine</i>	- - -	0.5
Water	- - -	0.5
		100.00

Vauquelin's analysis of this mineral^c con-

^b Analyt. Ess. p. 45.

^c An. de Chim. xxxvi. p. 146.

tains the following particulars. One hundred grains of gadolinite being ignited in a platina crucible lose about eight grains, and the colour of the substance becomes of an ochery yellow: but as during this process the iron has become oxydated the real loss of weight exceeds the eight grains by the amount of the oxygen absorbed by the iron, and this being about three grains, the whole loss by ignition must be set down as = 11 grs.

The analysis is thus effected. 1. The gadolinite being ground to a fine powder is digested with diluted nitric acid, and evaporated to dryness, taking care to increase the heat towards the end of the process, in order to ensure the complete oxydation of the iron. 2. The whole is now to be redissolved in water, and as the solution still contains a little iron this may be got rid of either by again evaporating to dryness and subsequent digestion in water, or by precipitating the iron by a drop or two of ammonia. 3. The solution is now mixed with caustic ammonia as long as any precipitate is produced; and the supernatant liquor and washings of the precipitate being mixed with carbonated potash a little *carbonat of lime* is thrown down. 4. The first precipitate No. 3. is redissolved in nitric acid, and by the cautions and gradual addition of hydro sulphuret of potash the *oxyd of manganese* is separated. 5. The clear liquor now only contains nitrat of *yttria*, from which the earth is procured by caustic ammonia. 6. The insoluble residues No. 2. consist of *silex* and *oxyd of iron*, which are separated by muriatic acid, the earth remaining undissolved.

Another method is, 1. To fuse the mineral with twice its weight of caustic potash, to digest the mass in boiling water, and then separate the liquor while hot from the undissolved portion by the filter. 2. The liquor will be of a fine green colour, indicating the presence of manganese, and by exposure to the air will become colourless, the oxyd of manganese being precipitated in the form of a black powder. 3. The clear liquor is now to be saturated with nitric acid, and the same menstruum very much diluted is to be digested on the insoluble portion No. 1. The two nitrous liquors being mixed together and evaporated to dryness, and redigested in water contain only the nitrats of lime and yttria; while the portion insoluble in nitric acid consists of *silex* and *oxyd of iron*, both of which are to be separated in the manner already described. From the results of these pro-

cesses Vauquelin states the component parts of 100 grs. of gadolinite to be

Silex	- - - -	25.5
Oxyd of iron	-	25.
Ditto manganese		2.
Lime	- - - -	2.
Yttria	- - - -	35
		89.5

Loss, consisting of
water and some carbonic acid - - 10.5

100.0

The particulars of the last analysis of gadolinite by M. Ekeberg being locked up in the Swedish language we are obliged to have recourse to a brief abstract published in the *Annales de Chimie*^d. From this it appears that M. Ekeberg followed the practice of Klaproth in separating the iron by fuccinat of soda, that he found no lime nor alumine, but a small portion of glycine: and that 100 parts of the entire mineral contain

Silex	- - - -	23.
Oxyd of iron	-	16.5
Glycine	- - -	4.5
Yttria	- - -	55.5
		99.5
Loss	- - - -	0.5

100.0

Notwithstanding the apparent differences in the preceding analyses it is satisfactory to find that most of them may be reconciled, or at least accounted for by a comparison of the different modes of operating adopted by their respective authors.

It is obvious that in M. Ekeberg's first analysis the proportion of iron is stated too high, and that of yttria too low, in consequence of his supposing that the sulphat of yttria is totally undecomposable by a red heat continued long enough to superoxygenate the sulphat of iron, and thus render it insoluble in water: for Klaproth in his preliminary experiments No. 6. has shown that a considerable part of the sulphat of yttria is also decomposed, together with the sulphat of iron. The way in which the proportion of alumine was ascertained is also liable to objection; for not only this earth but also

^d Tom. xlviii. p. 276.

glycine is soluble in caustic potash, and both are precipitable by carbonated ammonia provided this is not added to excess. It is also probable that simple digestion with muriatic acid would not separate the whole of the other earths from the filix with which they were at first combined; and this suspicion is further confirmed by the results obtained by Klaproth, who in his preliminary experiments found that 24.5 per cent. of this mineral was insoluble by digestion with muriatic acid; but in his analysis, when he used nitro-muriatic acid, and evaporated to dryness, there remained only 21.25 per cent. of insoluble matter.

In the analysis by M. Klaproth the amount of filix appears to be deduced in a perfectly unexceptionable manner, as well as that of the alumine; but the very same experiment which proves the quantity of this latter earth also shows the presence of 5.5 per cent. of glycine; for one of the essential characters of this substance is, to be soluble in caustic fixed alkali, by which it is distinguished from yttria, and another is, to be soluble in carbonated ammonia, by which it is distinguished from alumine. The oxyd of iron may be considered as fairly determined since M. Klaproth expressly mentions that the muriatic solution No. 3. was *largely* diluted with water before the addition of succinat of soda: if this had not been the case, there might have been a slight cause of error because succinat of glycine is very sparingly soluble in water, and a small quantity might therefore have fallen down with the succinat of iron.

Vauquelin's experiments clearly show that the substance which he operated on loses upwards of 8 per cent. by ignition, and this consists partly of water and partly of carbonic acid. The presence of manganese is also made very manifest, especially in the second mode of analysis, but the statement of its actual amount is not to be depended on, for the hydrosulphuret of potash in the first analysis No. 4. even when all possible caution is used, would be very apt to carry down a little earth along with the manganese: and in the second analysis No. 2. the caustic potash would dissolve not only the manganese but also a little black oxyd of iron, and both would spontaneously separate from the solution by exposure to air. The experiment indicating the quantity of lime cannot be objected to: but the mode of separating the filix, oxyd of iron, and yttria, is very erroneous. In the first place nitric acid is by no means so

active a menstruum as muriatic acid for these kinds of analysis; and in the next place if sulphat of yttria is in part decomposed at a temperature necessary to render sulphat of iron insoluble, it is extremely probable that the nitrats of yttria and iron stand in the same mutual relation: we may therefore set down the filix as somewhat exaggerated, the oxyd of iron as greatly so, and the yttria as diminished in at least an equal proportion. If however all possible allowance is made for the sources of error which have been just pointed out, still the great loss by ignition, the presence of manganese, which Klaproth expressly searched for in vain, and the difference in the external character, seem to render probable a suspicion that there is a real, though perhaps not amounting to a specific, difference between the substance analyzed by Vauquelin and the gadolinite examined by Klaproth and Ekeberg. With regard, however, to the absence of manganese from the gadolinite analyzed by Klaproth, it is to be observed that this able chemist has not particularized the experiments instituted by him to prove this point, and that the yttria even when considered by him as perfectly pure had a light cream colour, and when combined with sulphuric acid deposited crystals of a pale amethyst red, which may possibly have been occasioned by the presence of manganese, more especially as all the other earths when pure are snow-white, and afford colourless crystals with acids.

The analysis of gadolinite by Klaproth as fairly deduced from his own experiments would stand thus:

Silex	- - -	21.25
Oxyd of iron	- - -	17.5
Glycine	- - -	5.5
Alumine	- - -	0.5
Yttria with a trace		
of manganese		54.75
Water	- - -	0.5
		100.00

and when this is compared with the last analysis of this substance by Ekeberg the two will be found very nearly to correspond.

The following are the properties of YTTRIA as far as they have been examined.

Its specific gravity according to Ekeberg is ≈ 4.84 , a very remarkable character which has also been observed by Vauquelin. It is not reducible to the reguline state by heating with

charcoal, it runs during the process into a semifused mass, and its specific gravity is somewhat increased. It is insipid and inodorous, and insoluble in water. It is infusible *per se*, but with borax it forms a clear colourless glass.

It is insoluble in the fixed alkalies either pure or carbonated, also in caustic ammonia: but is readily dissolved by carbonated ammonia. The pure alkalies separate it from all its acid combinations. It is soluble in sulphuric acid, and the sulphat of yttria thence resulting crystallizes in rhomboids: it has a sweet somewhat astringent taste, is soluble in 25 to 30 parts of cold water, and requires nearly the same quantity of hot. It is decomposable by a red heat, the acid being volatilized. The muriatic and nitric acids also dissolve yttria, but the salts thence resulting are not crystallizable. Acetic acid forms with yttria a salt that crystallizes in four sided prisms. The neutral succinats decompose the muriat of yttria, producing succinat of yttria, which is very little soluble, and falls down in crystalline grains, except a large quantity of water is present.

Neutralized muriat of yttria is decomposable by prussiat of potash, a pearl-grey powder being precipitated, which however is resolvable in a slight excess of muriatic acid. It is also decomposable by pure tan, or by infusion of galls, but is only rendered turbid by gallic acid.

Oxalic acid and oxalat of ammonia throw down from the salts of yttria a white precipitate, which in its appearance and manner of subsiding bears a very near resemblance to muriat of silver.

Phosphoric acid does not decompose the sulphat, nitrat or muriat of yttria, but phosphat of soda occasions a white flocculent gelatinous precipitate.

The carbonated fixed alkalies decompose the salts of yttria, and produce a white pulverulent carbonat of yttria, insoluble in water, and composed according to Klaproth of

Yttria	- - - -	55
Carbonic acid	- - - -	18
Water	- - - -	27
		100

Yttria in its general properties and habitudes with acids bears a considerable resemblance to glycine. It is, however, distinguishable from this earth by its insolubility in caustic fixed al-

kali, its being precipitable by prussiat of potash, and its superior specific gravity.

GALENA. See LEAD ores of.

GALL animal. See BILE.

GALL NUT. *Noix de Galle*, Fr. *Gallapfel*, Germ.

Gall-nut is the produce of the prickly-cupped oak (*Quercus Cerris* Linn.) a small timber tree that grows wild in almost all the countries bordering upon the Mediterranean, and in some of the southern provinces of Germany. This substance is said to originate from a puncture made by an insect of the genus cynips, to the young of which, while in their larva state, it serves for habitation and food. It is found adhering to the soft annual shoots of the tree, and in short, in its original situation and general appearance is considered by naturalists as precisely similar to those excrescencies on our English oaks, vulgarly called *oak-apples*. There are two kinds of gall-nut distinguished in commerce; the inferior is of a pale brown colour, and about the size of a nutmeg, and is procured from Spain, France, and the northern Mediterranean countries; the superior sort is of a deep olive colour, approaching to black, is smaller than the other, and its specific gravity is considerably greater: it is produced in Asia Minor, but more especially in Syria, and is hence called the Aleppo gall, this town being the principal seat of the foreign Syrian commerce.

Notwithstanding however the concurrent testimony of naturalists as to the original of the gall-nut, any person who will give himself the trouble to break half a dozen *sound unperforated* Aleppo galls may readily convince himself that this is one of those vulgar errors which are repeated and believed from generation to generation, because in philosophy and natural history it is easier to believe than to examine.

Gall-nut consists of four parts. The external or *cortical* covering is of a dense fibrous texture, a pale yellowish white colour, is very thin, and separable without much difficulty from the part which it encloses: to the taste it is highly astringent, with a slight, and sometimes a scarcely perceptible bitterness: when laid on a red-hot iron it smokes and blackens, and finally becomes ignited, but without any flame: the smok is slightly pungent, accompanied by a peculiar and indescribable odour, which, however, chiefly characterizes the resinous part of the gall-nut. Immediately beneath the cortical part lies that which, merely from its external appearance, we shall call the *resinous* part, and

which constitutes by far the greater portion of the gall-nut: the colour of this is dark yellowish brown: it has a fibrous texture, and shows a great tendency to a conchoidal fracture: it has a glimmering resinous lustre, and is very brittle: it is not only astringent to the taste, but nauseously bitter, and appears almost entirely soluble in the saliva: when laid on a red hot iron it becomes black, and in a state of semifusion, and exhales very copiously that peculiar odour which we have already mentioned; in a short time it is ignited, and reduced to ashes, but without producing any flame. The central cavity of the gall-nut is lined with a very pale yellowish brown *shell*, adhering pretty firmly to the resinous part; it is of a fibrous texture, without lustre; to the taste it is almost wholly insipid like common ligneous fibre, and, like this, when laid on a red hot iron it burns with a yellowish flame and a copious production of very penetrating pyroligneous acid. Within the shell is contained the *kernel*, which is a small egg-shaped body, sometimes considerably flattened, and a quarter of an inch or more in length: it is of a brown cream colour, and an even very minutely granular fracture like a common hazle nut; it breaks down between the teeth like all the oily farinaceous seeds when dried: it is insipid, but after being chewed leaves a faint sweetish flavour like that of a bad almond: it is often found mouldy, and then is of a bright chocolate colour. When laid on a hot iron it becomes somewhat moist, and gives out a pungent empyreumatic acid in great quantity, but without flaming, and is probably little else than amylaceous fecula. This kernel no doubt it is which invites the depredation of insects; and in all those gall-nuts the kernels of which have been devoured, may be perceived a small tubular passage from the outside to the centre, and in the place of the kernel is generally left a little web, and some minute black grains which probably are the excrements of the insect. Gall-nuts that are unperforated are sometimes however found hollow, but this may be inferred to be owing to the destruction of the kernel by spontaneous decomposition, on account of the mouldy and discoloured state of the remaining shell.

No chemical analysis has been made of any one of the four parts of the gall-nut separated from the rest, although what we have called the resinous portion seems to be particularly interesting: the gall-nut in general, however,

has been subjected to several curious enquiries by Scheele, Deyeux, Proust, Davy, and others, of which the following are the principal results.

When bruised galls are infused in distilled water at the temperature of about 60° Fahr. a dark brown fluid is obtained in the space of a few hours; this being poured off and another portion of water being added a second infusion is procured of a somewhat lighter colour than the former; after having thus employed four or five separate parcels of water the succeeding infusions exhibit a yellowish green tinge, which by degrees becomes more and more faint, till all that portion of gall-nut soluble in this menstruum at the above temperature is taken up. According to Deyeux^a it requires 96 quarts of water divided into 20 different macerations to exhaust all the soluble matter of a single pound of galls. The brown infusion acquires a deep black colour by red sulphat of iron indicating the presence of gallic acid, a solution of isinglass in water occasions in it a copious precipitate, indicating tan, and muriat of alumine throws down a precipitate denoting the presence of extract. This brown infusion seems to be furnished almost entirely by the resinous part of the nut. The light green infusion gives a deep blue precipitate with red sulphat of iron, but is hardly at all affected by the other two reagents; it appears to contain little else than gallat of lime, and is probably furnished by the cortical covering of the gall-nut. A few drops of moderately strong sulphuric or muriatic acid change the green tinge of this infusion to red, after which the original colour may be restored by the addition of an alkali, and deepened if it is added to excess. The concentrated nitric and oxygenated muriatic acids destroy the colour of the infusion, nor can it be restored by an alkali. By long continued slow evaporation the green colour is changed into a dirty yellow, and then neither acids nor alkalis act on it in the same manner as before.

The strongest brown infusion that can be made by macerating pounded galls with distilled water at 56° Fahr. is of the specific gravity of 1.068, and yields by evaporation a little more than $\frac{1}{8}$ of solid matter.^b The solution is nearly transparent, of a yellowish-brown colour and a sour and highly astringent taste; it strongly reddens litmus and shows other proofs of a disengaged acid. When sulphuric acid is poured into the infusion, a dense white precipitate is

^a An. de Chim. xviii. p. 11.

^b Davy in Phil. Trans. for 1803.

thrown down, and the supernatant liquor becomes of a deeper colour than before: it is not however by this process freed entirely from any of its ingredients, since it still continues to give a deep black with the oxygenated salts of iron, and to afford a precipitate with gelatin. The sulphuric precipitate when separated by the filter, slightly reddens vegetable blues, yields gallic acid by distillation, and when dissolved in warm water gives a copious precipitate with isinglass. Muriatic acid produces a similar effect on the infusion to that of sulphuric acid. Strong nitric acid when first added to the infusion renders it turbid, but the separating matter is soon dissolved with effervescence and the liquor becomes clear and of an orange colour: the excess of acid being saturated by an alkali, both the tan and gallic acid of the infusion are found to be destroyed, for no precipitate is occasioned by a solution of gelatin, nor any change of colour by red sulphat of iron. By evaporation, a soft yellowish brown substance is procured, which from its decomposing nitro-muriat of tin and nitrat of alumine, appears to be a kind of extract. If a very diluted nitric acid is employed, its effects on the infusion are similar to those of the sulphuric and muriatic acids.

A solution of either of the fixed alkalies in a perfectly caustic state occasions a temporary turbidness in the infusion and changes its colour to brown-red: in this state it gives no precipitate with gelatin till the addition of an acid, when a copious sediment is produced. Caustic ammonia at a moderate temperature has the same effect as fixed alkali, but when the mixture is exposed to the heat of boiling water, part of the ammonia is volatilized and the remainder reacts on the tan and gallic acid of the infusion, converting them almost entirely into a substance precipitable by muriat of tin and the aluminous salts.

If instead of a perfectly caustic fixed alkali, one that is only partially so be employed, a precipitate is thrown down from the infusion, the quantity of which varies in proportion to that of the carbonic acid united with the alkali. That the formation of this precipitate depends on the presence of carbonic acid is manifest from this circumstance, that if carbonic acid gas is passed through the residual clear liquor, consisting of caustic alkali and infusion of galls, an immediate precipitate is occasioned, which exhibits the same properties as that produced by carbonated alkali in the infusion. The following are the characters of the precipitate: it

has not the astringent taste of uncombined tan; it is but imperfectly soluble in cold water or alcohol; when digested in a large quantity of hot water it is separated into an insoluble and a soluble part; the former of these is not acted on by alcohol, it is partially soluble in muriatic acid, and the solution precipitates gelatin and the salts of iron; when incinerated it affords a considerable proportion of lime but no alkali; hence it appears to be a compound of lime, gallic acid, tan, and perhaps a little extract: the part soluble in hot water is incapable of precipitating gelatin till the alkali is saturated by an acid, and when incinerated it yields carbonated alkali.

The alkaline earths when added in substance or in solution to the brown infusion of galls, combine with the whole of the tan and throw down a green precipitate: the supernatant liquor is also of a green colour, which becomes more intense by exposure to the air: it is made turbid by sulphuric acid and gives a black precipitate with the salts of iron, and consists of gallic acid and probably some extract combined with part of the alkaline earth. The green precipitate by repeated washing with water gives out nearly the whole of its gallic acid, and the residue is little else than tan with the alkaline earth. The artificial carbonats of these earths produce the same effect as the pure earths.

If alumine is boiled with the infusion it becomes of a yellowish grey tinge and combines with the whole of the tan and extract, and nearly the whole of the gallic acid; the supernatant liquor being clear and colourless and giving a very faint purple with red sulphat of iron: if only a very small proportion of alumine be employed, the liquor consists of gallat of alumine with excess of acid.

The perfect oxyds of tin and zinc prepared with nitric acid, when boiled with the infusion become of a dull yellow colour and reduce the supernatant fluid to mere water: the yellow oxyds are soluble in muriatic acid, and then give a copious precipitate with gelatin and a dense black with salts of iron.

The compound earthy and alkaline salts also decompose the infusion of galls, but the precipitate is not pure tan as has been supposed, for it contains besides some gallic acid, extract, and the precipitant salt. The same may be observed of most of the metallic salts.

When the brown infusion is exposed to gentle evaporation, it first becomes turbid by the deposition of part of its extractive matter, and at length acquires the consistence and appearance

of a tough brown extract, which while it is warm may be moulded like Chio turpentine, but when it becomes cold is dry and hard and very easily pulverizable. By exposure in close vessels to a heat superior to that of boiling water, the mass first softens, then swells and gives out a prodigious quantity of carbonic acid; there sublimes at the same time a white salt in needles and scales, which is pure gallic acid: soon after a fluid arises in which the gallic acid dissolves, and this is succeeded by a thick black oil; at this period the gas, which hitherto has been carbonic acid, becomes inflammable, and so continues till nothing but a dry coal is left in the retort.

An exact analysis of galls is for the present at least impracticable, since we are not acquainted with any reagents that will separate any of its component parts unmixed with the others: upon the whole perhaps the best mode of proceeding is as follows. Take any quantity of galls and reduce them to powder, then by means of repeated infusions with water at a temperature less than that of ebullition, extract every thing that is soluble. The residue being thoroughly dried will indicate with considerable exactness, by means of its loss of weight, the amount of soluble matter. All the different infusions being mixed together are to be evaporated at a very gentle heat to a small bulk, during which some reddish-brown extract will be deposited and must be carefully separated and dried; the residual fluid by subsequent evaporation is to be brought to a solid state and then digested in pure alcohol, by which the tan, gallic acid, and extract will be taken up, while the mucilage mixed with some impurities will remain insoluble and may thus be separated. The alcoholic solution being again evaporated, the residue is to be dissolved in water, and a strong solution of isinglass is to be poured in as long as any precipitation takes place: this precipitate when well washed consists of tan, and gelatin with a very little extract and gallic acid, and contains about 46 per cent. of tan. The rest of the solution is gallat of lime with excess of acid, and a little extract.

According to Davy, 500 grains of good Aleppo galls contain 185 grains of matter soluble in water, and this consists of

	grains.
Tan - - - - -	130
Mucilage and extract deposited } during evaporation - - }	12
Gallic acid with a little extract	31
Lime and saline matter - -	12

For further particulars concerning gall-nut see Gallic acid, Ink, and Tanning.

The uses of this substance are very important. It is employed largely in dyeing not only blacks and various kindred colours, but is also an essential ingredient in the composition of the finest madder reds: it is a necessary part of all the black writing inks: it is employed in the laboratory as a useful test for the salts of iron, and is occasionally used in medicine.

GALLIC ACID. *Acide Gallique*, Fr. *Gallussäure*, *Gallapfelsäure*, Germ.

The existence of an uncombined acid in galls and in various other astringent vegetable substances, was suspected by Macquer, Lewis, Monnet, and other able chemists, but was not demonstrated till the year 1772, when Morveau and the other Dijon academicians took the subject in hand. They found that the infusion of galls changed vegetable blues to red, was capable of decomposing the alkaline hydrofulphurets, of dissolving metallic iron, and of decomposing and precipitating the solutions of several metallic salts. The subject remained in this state till 1780, when Scheele put the matter beyond doubt by publishing a method of separating the acid from the other ingredients of the gall-nut. This acid obtained the name of the gallic from the substance which yields it the most easily and in the greatest plenty, and has ever since taken its place among the other native vegetable acids.

The method employed by Scheele to obtain the gallic acid is the following. Take any quantity of Aleppo galls, and having reduced them to a coarse powder digest it in three or four successive portions of scalding water, by which almost all the soluble part will be extracted; then add together all the infusions, and a brown turbid liquor will be obtained, intensely astringent and somewhat acid: put the liquor into a large uncovered basin and set it by in a warm room for two or three months: in a few days a covering of mould will appear on the surface, which must be occasionally broken and stirred into the liquor. In proportion as the process of moulding goes on, the astringent taste of the fluid becomes weaker and the acid taste increases, at the same time a dirty brown sediment mixed with crystalline grains is deposited. When the whole is evaporated to dryness or nearly so, the remainder is to be digested in about an equal weight of hot rectified alcohol, and the liquor is to be passed as hastily as possible through a filter. The undissolved residue is to be a second time digested in half the quan-

tity of the alcohol used at first, and this second solution after filtration is to be added to the first. The liquor as it cools will deposit some brown crystalline grains, and fresh portions may be procured by successive evaporation and cooling. These impure crystals being a second time dissolved in as small a quantity as possible of hot alcohol, will separate by cooling in the form of small grains of a brownish yellow colour, and in this state form the gallic acid of Scheele. But the acid thus prepared is by no means pure, it not only contains a little extract by which it is coloured but (what has not been adverted to) it also contains lime, and that in no small quantity; for when dissolved in water and neutralized by carbonated soda, a coloured precipitate falls down, and the supernatant liquor after a short exposure to the air becomes of a deep green colour. In order therefore to purify this acid the best method is to rub it up with an equal weight of dry charcoal, and then heat it in a very short necked retort with an attached receiver: the heat must be just sufficient to disengage white fumes from the mixture and no more; these fumes passing into the receiver will concrete there and line the whole inside of the vessel with long silky crystals of a silvery whiteness, which are pure gallic acid. The loss of weight in this process is considerable, but not more than might be expected when it is remembered that the produce is only the excess of acid beyond what is necessary to neutralize the lime which the native acid contains. Instead of employing the acid of Scheele for this purpose the gall-nut in substance may be subjected to dry distillation; there first arises a watery acid liquor, then white crystals of gallic acid, which are soon however succeeded by a brown oil which soils and dissolves them if the process is not stopped in time. Probably the addition of dry pounded charcoal would detain the oil, and thus both facilitate the operation and augment the produce.

A new method of obtaining pure gallic acid has been proposed by M. Fiedler.* It consists in digesting the watery infusion of galls with alumine, and procuring from the clear liquor by slow evaporation needle-form crystals. But these are probably not pure gallic acid but only acidulous-gallat of alumine.

Pure gallic acid is in the form of white brilliant needle-form crystals, of a sour pungent taste and somewhat austere. At a heat somewhat exceeding that of boiling water it becomes fluid and of a slightly brown colour, thus indi-

cating a partial decomposition; at the same time it gives out white vapours, which have a faint sub-aromatic odour and concrete by cooling into white crystals as at first. While solid it is not sensibly acted on by the air. It requires about 24 parts of cold and three of hot water for its solution. It powerfully reddens vegetable blues and exhibits the usual characters of an acid. When dissolved in water it shows a strong tendency to decomposition, the solution becomes coloured, as also are the crystals which it yields by evaporation. Cold alcohol will dissolve about a fourth of its weight of this acid, and at a boiling temperature will take up full its own weight.

By concentrated sulphuric acid it is charred and decomposed: strong nitric acid converts it into a mixture of malic and oxalic acids. Oxymuriatic acid also decomposes it, but the mutual action of these two substances has not been sufficiently examined. The other acids dissolve gallic acid, but without occasioning any immediate change.

It combines with the alkalies and alkaline earths, forming salts of little solubility, but the properties of which have not been investigated.

In consequence of the ready decomposition of this acid and the large proportion of carbon that it contains, it precipitates gold, silver, mercury, copper, bismuth and iron from all their acid combinations, reducing the two first in part to the metallic state. It appears incapable of decomposing the salts of platina, zinc, tin, cobalt, and manganese. The oxygenated salts of iron are thrown down by it, of a deep blue colour approaching to black, and this is its most characteristic property. It is not used in its pure state, but as a component part of GALLS and other astringent vegetables. It is applied to a variety of important purposes, for which see especially the articles DYEING and INK.

GAMBOGE. *Cambogia Gutta.*

The gum-resin, commonly called gamboge, is the produce of a middling-sized tree that grows wild in Ceylon, Siam, and Cochin-China, and is called by botanists *Stalagmitis Gambogioides*. The Siamese gamboge is in small tears formed by the concretion of the drops of juice as they fall from the leaf-stalks, and young shoots when they are broken off from the tree. In Ceylon the juice is procured by deep incisions in the bark, and is afterwards inspissated by the heat of the sun and moulded into cakes or rolls. When pure, its colour is a deep rather dull orange, its fracture is conchoidal and somewhat

* Van Mons's Journ. de Chim. i. p. 85. or Nicholson's Journ. 8vo. i. p. 236.

shining. It has no smell and very little taste, but when kept in the mouth for some time it gives a slight impression of acrimony. If applied to the flame of a candle it melts and blazes, throwing out sparks and emitting a dense black smoke.

Gamboge is not properly soluble though extremely diffusible in water, with which it forms an opaque yellow-coloured infusion: by passing the liquor through a filter some resin is detained, but the fluid still continues coloured and turbid. Alcohol is a more effectual solvent for this substance, which it takes up in large quantity and forms a clear gold-coloured fluid: on the addition of water the alcoholic solution becomes turbid like the watery infusion. Of 16 ounces of gamboge, water, according to Neumann, will take up 13 ounces, and of the residue 2 ounces are soluble in alcohol: of an equal quantity alcohol will first dissolve 14 ounces, and of the residue one ounce is soluble in water; the insoluble matter in both cases amounting to $\frac{1}{16}$ of the whole. Both the fixed alkalies and ammonia effect almost a total solution of gamboge, producing a clear liquor of a deep and rich red brown colour, and the residuum being pure gum is entirely soluble in water. The addition of an acid to the alkaline solution throws down a copious yellow precipitate, which when dried presents an earthy fracture, is difficultly combustible and does not melt like the pure resin.

Gamboge, besides its medical application, is extensively used as a water colour, and its tincture in alcohol is one of the ingredients of the gold coloured lacquer with which most of the smaller articles that are made of brass are overlaid: it is also employed by the inlayer and cabinet-maker to stain white woods in imitation of box, &c. See the article VARNISH.

GARNET. ^a Grenat, Fr. Granat, Germ.

The colour of garnet is blood or cherry red; when mixed with blue it passes into crimson and violet red, and when tinged with yellow into hyacinth red; it is also met with of a reddish brown colour, liver brown and black, also greenish-yellow, greenish-brown, and greenish-black. It occurs in mass, disseminated, in angular fragments, or crystallized. Its primitive figure is the rhomboidal dodecahedron, which when somewhat lengthened presents the appearance of a short six-sided prism, the faces of which are parallelograms terminated by trihedral summits with rhomboidal faces. Sometimes the original faces of the dodecahedron entirely

disappear, and the result is a solid bounded by 24 equal and similar trapeziums. Sometimes all the sides of the primitive dodecahedron are replaced by lengthened hexagons, whence results a solid bounded by 12 rhombs and 24 hexagons. Other more complicated figures, but which cannot be rendered intelligible by mere description, originate from the mixture of the two preceding modifications. The size of the crystals is subject to great variations; some are no larger than a pin's head, while others are four inches or more in diameter. The external lustre is casual but generally glistening; the internal lustre is bright-shining, vitreous. Its fracture is perfectly conchoidal passing into imperfectly conchoidal, coarse grained uneven, or splintery. Its fragments are indeterminately angular and sharp-edged. It sometimes occurs in granular or lamellar distinct concretions. It varies from transparent to translucent on the edges. Its hardness is superior to that of quartz. Sp. gr. 3.7 to 4.2.

It is often magnetic, and is fusible without much difficulty before the blowpipe into a black enamel. When strongly heated in a charcoal crucible it affords a grey dusky glass full of grains of iron, often amounting to 10 or 12 per cent.

This mineral has been repeatedly analyzed by Klaproth, Vauquelin, and other able chemists, but without much agreement in the results; and as in general the same method of analysis has been adopted, the remarkable differences which have occurred can only be attributed to a real variation in its composition: they all agree however that it contains a large proportion of iron, and possibly this ingredient may be the one which principally influences its crystallization.

The Bohemian garnet has been analysed by Klaproth ^b and Vauquelin, ^c with the following results.

	Klapr.	Vauq.
Oxyd of iron - -	16.5	41.
Oxyd of manganese - -	0.25	0.
Silex - - - -	40.	36.
Alumine - - - -	28.5	22.
Lime - - - -	3.5	3.
Magnesia - - - -	10.	0.
	98.75	102.

The Sirian garnet, according to Klaproth, contains

^a Emmerling, Haüy, Brochant, Jamefon.

^c Journ. des Mines, No. 44. p. 571.

^b Analyt. Ess. I. p. 335.

Oxyd of iron	- - -	36.
Oxyd of manganese	- - -	0.25
Silex	- - - - -	35.75
Alumine	- - - - -	27.25

99.25

Besides the above the following analyses of garnets have been made by Vauquelin.

	Black G. from Pic d'Ereids.	Red G. from ditto.	Yellowish amorph. G. from Corfica.
Oxyd of iron	16. —	17. —	10.
Silex	- - 43. —	52. —	38.
Alumine	- - 16. —	20. —	20.
Lime	- - 20. —	7.7 —	31.
	95.	96.7	99.

The most beautiful and valuable garnets are the oriental. They come principally from Pegu; and the town of Sirian having been formerly the chief mart for them, they are hence by corruption known among lapidaries by the appellation Syrian garnets. They appear to be the *Carbuncle* of the ancients: their colour is crimson verging into a very red violet; they are transparent and have a conchoidal fracture: of their geological situation we are entirely ignorant.

Next in estimation to the oriental is the Bohemian garnet (Pyrop of Werner). It is met with in the Mittelgebirge of Bohemia and in Saxony: its colour is blood-red verging into yellow: it never occurs crystallized but only in rounded and angular grains: it is transparent; its fracture is conchoidal. It occurs in floetz-trap and in alluvial land, formed by the decomposition of this class of mountains; it is also met with in serpentine.

Common garnet occurs almost always in primitive rocks, especially in micaceous schistus, chloritic slate and serpentine: it is sometimes so abundant as to constitute the principal part of the rocky mass in which it is found, which is then an excellent flux for iron ores on account of its fusibility and the large quantity of this metal which it contains.

The Oriental and Bohemian garnets when cut and polished are very beautiful, and were formerly (particularly the first) in high estimation, but by the caprice of fashion their employment and consequently their value has of late very much declined.

GARNET (black). See MELANITE.

GARNET (white). See LEUCITE.

GAS. The term gas, in chemistry synonymous with *air*, is employed to signify any

invisible elastic aeriform fluid, permanent at the common temperature of the atmosphere, and (with the single exception of the oxymuriatic acid gas) not condensible by any known degree of cold natural or artificial. The discovery of the existence and properties of the gasses is the peculiar strength and boast of modern chemistry, and in fact this branch of the science may be said to be created by the multiplied and ingenious labours of chemists still living or lately dead, such as Priestley, Scheele, Cavendish, Lavoisier, Berthollet, and others.

The chemical description of the various gasses will be found in their respective places, but a summary view of them, and some of their characteristic properties may be given here, together with some other general properties, and in particular the methods employed in analysis of estimating truly their actual quantities, in which more precautions are required than in examining any other class of natural bodies.

Strictly speaking, every gas, however simple in its nature, is a compound of the basis of the gas, and of that additional quantity of caloric which is required to enable it to assume the gaseous form, and it is sometimes of consequence to consider the latter as distinct from that other portion of caloric which must of course be combined with the basis without inducing any change of form.

Thus muriatic acid gas is composed of the hitherto undecomposed substance of muriatic acid, (which, like every other body in nature, has its natural inherent portion of caloric,) and also of that additional quantity of caloric which constitutes it a gas. Hence when this gas is passed through water, the acid combines with it, loses its gaseous form and becomes liquid, and the caloric thereby set at liberty very sensibly raises the temperature of the water.

It is therefore an inaccuracy of terms though very commonly used to speak of the combinations of gaseous bodies with solids or fluids instead of the *bases* of these gasses, as where a metal is said to be oxidated by union with oxygen gas, instead of *oxygen* the basis of this gas; or where water is said to hold in solution carbonic acid gas instead of carbonic acid. This inaccuracy particularly arises from the circumstance that we can never exhibit these substances, such as oxygen, hydrogen, or azot, in any form more simple than that of a gas, in which is combined only with an excess of caloric.

The following are the gasses at present known, with some of the leading characters by which they are distinguished in analysis.

Oxygen Gas is sparingly absorbed by water, supports flame and combustion in an eminent degree, is analyzed by nitrous gas, which it converts totally into nitric acid; is absorbed by the combustion of phosphorus, and by the sulphurets.

Azotic Gas is hardly absorbed by water, extinguishes flame, dissolves phosphorus, becoming thereby enlarged about $\frac{1}{6}$ of its bulk, and then is luminous on the admission of common air or oxygen—when combined with oxygen by the electric spark produces nitric acid.

Carbonic Acid Gas is readily absorbed by about its own bulk of water, and in much greater quantity by lime, barytic, or strontian water, or by all the alkalies when pure or only partially carbonated—gives a white precipitate with the solutions of the above-mentioned earths, which it redissolves if it is in excess, and which is soluble in any other acid with effervescence.

Carbonous Oxyd Gas is scarcely absorbed by water, is but little lighter than common air, burns in air with a large white flame, and produces by its combustion only carbonic acid gas.

Hydrogen Gas is scarcely absorbed by water, is remarkably light, when kindled burns gradually at the point of contact with common air or oxygen with a faint blue flame without smoke; or when previously mixed with common air or still more with oxygen, and kindled, burns instantly with a violent explosion, and in both cases with the production of much moisture—dissolves sulphur, phosphorus, carbon, and some of the metals, forming gasses, which partake of the properties of each of their constituents, such as,

Sulphuretted Hydrogen Gas, which has a strong and fetid smell, is readily absorbed by water, burns with a greenish-blue flame, readily blackens the colourless solutions or white oxyds of many metals, particularly lead, silver, mercury, iron, and bismuth, when in solution with water is decomposed by nitric acid and deposits its sulphur.

Carburetted Hydrogen Gas has a strong peculiar smell, is lighter than common air, little absorbed by water, burns in air with a white-blue flame and much smoke, and the production both of carbonic acid and water.

Olefiant Gas resembles the latter in many of its properties, but is distinguished by generating an oil when mixed with oxymuriatic acid gas.

Arsenicated Hydrogen Gas resembles pure hydrogen in most of its properties, but has a peculiar and most offensive smell, and deposits arsenic by standing, and produces arsenic acid by combustion with oxymuriatic acid.

Phosphuretted Hydrogen Gas is absorbed by water, has a fetid and characteristic smell, burns spontaneously with a slight explosion at the common temperature, as soon as in contact with oxygen or common air.

Ammoniacal Gas is absorbed instantly and abundantly by water and most other fluids, has a peculiar and most pungent smell, forms neutral ammoniacal salts with all the acids, produces dense white fumes around any substance moistened with muriatic acid, or particularly when mixed with muriatic acid gas.

Sulphureous Acid Gas has the peculiar smell of burning sulphur, is absorbed instantly and abundantly by water, first reddens and then destroys many vegetable colours, and dissolved in water forms the liquid sulphureous acid.

Muriatic Acid Gas, though invisible by itself, forms white vapours when in contact with air, has a pungent smell and excites violent coughing, is copiously absorbed by water, giving out much sensible heat thereby, and then forms the common liquid muriatic acid, gives dense white fumes with ammoniacal gas, or the mere proximity of liquid ammonia.

Oxymuriatic Acid Gas has a very peculiar and very suffocating smell, is absorbed by water in a moderate degree, and when to supersaturation, crystallizes in part on cooling, in thin plates; when unmixed with muriatic gas it destroys vegetable colours without previously reddening them, ignites spontaneously many of the metals and metallic sulphurets, such as arsenic, antimony, orpiment, and zinc; when added to it in fine powder; dissolved in water it forms a liquid of an acerb but not acid taste which acts on gold and platina.

Fluoric Acid Gas resembles the muriatic but gives a precipitate with lime-water, and when prepared in a glass vessel corrodes it, and, being then received in water, is copiously absorbed by it, each bubble leaving a singular deposition of a siliceous film in delicate cylindrical tubes.

Nitrous Gas is scarcely at all absorbed by water, but when standing over this fluid gives copious red fumes, on admitting common air, and especially oxygen gas, and is by the latter totally converted into nitric acid which is then absorbed by the water. Nitrous gas is copiously absorbed by the green sulphat or muriat of iron, producing an olive-brown liquor which immediately absorbs oxygen from any air with which it is mixed.

Nitrous Oxyd Gas resembles oxygen in eminently supporting and encreasing combustion in most cases, but extinguishes sulphur when in

feeble combustion; is absorbed in a considerable proportion by water, and undergoes no diminution when mixed with nitrous gas.

To this list of the known gasses several modifications of some of the species might perhaps be added, particularly those in which ether enters as a constituent part, such as the etherized nitrous gas and others. It is still not quite determined whether *atmospheric air* should be considered as a peculiar chemical compound, or a simple mixture, and therefore imitable by the mere combination of azot oxygen and carbonic acid in the due proportions.

The absorption of the different gasses by water is attended with some circumstances worthy of remark. With the easily absorbable gasses the absorption is much affected both by the purity of the air employed, and by its actual quantity proportional to that of the water. Thus according to Mr. W. Henry's experiments,^a if 20 measures of carbonic acid be agitated with 10 of water at 55° temperature, at least 10 measures will be absorbed, but if the 20 measures be previously mixed with 10 of common air, only 6 will be absorbed. On the other hand water agitated with twice its bulk of carbonic acid gas, will (other things being alike) take up more of the gas than with a less quantity, though still more than will saturate the water. The reason of these two facts appears to be the affinity which exists between carbonic acid gas and common air, and which opposes the absorbing action of water, since this fluid will always absorb the carbonic acid in preference to the common air, and in so doing therefore will break the union between the two; and indeed when the water previously contains common air, the act of absorption of carbonic acid will expell this common air by superior affinity. Hence the well-known law of affinity comes here into action, namely, that the decomposition of two bodies by the superior affinity of a third, is constantly becoming more and more difficult as the relative proportion of the two first becomes more unequal, and often ceases altogether before the decomposition is complete. Of this there are numerous instances in chemistry, that is, where a large proportional mass of one substance will protect a small portion of another with which it is united, from the decomposing action of a third, however superior its real chemical affinity may be. Therefore in the above instance common air adheres to carbonic acid gas by a considerable affinity, which the superior affinity of water can break only

partially, and there is a certain point in which the proportion of the common air is so great compared with the carbonic acid, as entirely to prevent the further separation of the two by the absorbing power of water. The addition of a quantity of common air to the carbonic acid will therefore obviously diminish the absorption of the latter; and on the other hand a large bulk of carbonic acid gas (which always contains some little impurity of common air) will afford a larger absorption to the water than a smaller bulk, as the mixed gasses can in the former instance spare a larger quantity of pure carbonic acid before the mixed residue arrives at the undecomposable proportions, than in the latter. This counteracting affinity of carbonic acid gas and common air, is strikingly illustrated by an observation of Dr. Brownrigg, who observes with some surprize that though the natural Spa water (which is chiefly a strong solution of carbonic acid in water) violently bubbles and loses its condensed carbonic acid when in free contact with the atmosphere, this is not merely owing to the removal of mechanical pressure from the surface of the water (either naturally when the spring bursts out into day, or artificially, by drawing the cork of the bottle in which it is confined) since when an empty bladder quite air-tight is attached to a bottle containing the water, no gas flies up into the bladder though all mechanical pressure is removed by this contrivance. It is therefore the contact of atmospherical air that causes the escape of the carbonic acid, owing to the strong affinity existing between the two gasses, and as the bulk of the atmosphere is immense, the relative proportions between it and the carbonic acid continue the most favourable for the strongest affinity, both as to the comparative bulk and composition of the atmosphere.

Temperature also much affects the absorption of gasses by water, this being the greatest when the temperature is the lowest, as would indeed be expected owing to the encreased elasticity, and therefore inaptitude to absorption, which is given to gasses by adding caloric. At a heat even inferior to boiling no gas can be combined with water, but all already combined are expelled, a minute portion excepted, which no known means can entirely remove, but is perceptible by its effects. The gas is thus extricated from any mineral water to be examined simply by boiling the water for about a quarter of an hour and carefully collecting the aeriform products.

Pressure is another circumstance that affects

^a Phil. Trans. vol. 89.

the absorption of gasses. Mr. Henry found by sufficiently accurate experiments that under equal circumstances of temperature, water takes up in all cases the same volume of condensed gas as of gas under ordinary pressure. Hence as the volume of any gas is simply in inverse proportion to the compressing force, the quantity absorbable under any circumstances of pressure is readily known from the result of experiments made under any other pressure.

Thus a pressure equal to two atmospheres, or about 58 inches of mercury, on a quantity of gas, will cause just twice as much in weight to be absorbed by water as under ordinary pressure, and hence the great importance of machinery for giving pressure, in the different apparatus employed to make the artificial mineral waters.

We may add to this part of the subject the results of Mr. Henry's experiments on the absorption of many of the gasses.

One hundred cubic inches of water absorb, of

	Temperature.	cub. inch.
Carbonic acid gas	at 55° —	108.
Sulphuretted Hydrogen	60° —	108.
Nitrous Oxyd - - -	60° —	77.
Nitrous Gas - - -	ditto —	5.
Oxygen - - -	ditto —	3.55
Phosphuretted Hydrogen	ditto —	2.14
Carbonic Oxyd - - -	ditto —	2.01
Carburetted Hydrogen	ditto —	1.40
Azotic Gas - - -	ditto —	1.47
Hydrogen - - -	ditto —	1.53

The absorption of atmospheric air cannot be well estimated as it is partially decomposed by water, the oxygen being absorbed in preference to the azot.

* * *

In the chemical examination of gaseous bodies, especially in the nicer researches of decomposition, it is of great importance to exclude all extraneous bodies and particularly *moisture*. All gasses probably without exception are capable of holding in solution very variable quantities of moisture, and as this latter is decomposable into oxygen and hydrogen by the electric spark and other methods, much error may be induced from this source. The state of moisture or dryness of common air is indicated by the hygrometer, an instrument the use of which hardly comes under the province of chemistry. So eager is the attraction of dry air for moisture that if a quantity be shaken for an instant with

a few drops of water in a small vessel, it almost immediately becomes so far saturated with it as strongly to affect the hygrometer.

For chemical purposes, gasses are rendered of an uniform, at least, if not perfect state of dryness, either by passing them through a heated tube, or better by exposing within them some substance which itself strongly attracts moisture. Several of these are used apparently with equal effect. A small quantity of concentrated sulphuric acid, a piece of fused caustic potash, or some dry powdered muriat of lime, will all answer the same purpose, and render the gas within uniformly dry when suffered to remain in contact with them for about an hour.

* * * *

In all experiments on gasses, it is necessary in order to give comparable results, to pay attention to some circumstances that influence their apparent quantity and bulk. These are, the *Expansion by Heat*, and consequent contraction by cold, and the change in volume produced by the degree of *Pressure*, both atmospherical, and that which is often occasioned artificially by the mode of confining the gas by the apparatus employed.

1. Of the Expansion by Heat.

Gaseous bodies expand immediately and very largely (comparatively with other natural bodies) by any addition of heat, and hence they form by far the most delicate material for thermometers, though their use is much lessened by the counteracting and superadded effect of pressure.

Many experiments have been made on the expansion of common air by heat, and the rate of enlargement has been given with considerable variation. But the accurate experiments of Dalton in England and Lussac in France, are found to coincide so closely and were both conducted with such apparent accuracy that we may safely adopt them in our calculations.

Mr. Dalton^b found repeatedly that 1000 parts of common air at 55° temperature (dried by the contact of sulphuric acid, and under unvarying atmospherical pressure) expanded to 1321 parts when heated from this point to 212° in a manometer tube, to which 4 parts must be added for the corresponding expansion of the glass, and hence 325 parts are the increase upon 1000, by 157 degrees of heat, carried up to 212°. This therefore gives 2.07 increase upon 1000 parts of air by the addition of a single degree of heat, from 55° to 212°. The expansion however appeared to be not quite equal for equal

^b Manchester Mem. vol. v. pt. 2.

increments of heat, through the whole scale; for it was found to be 167 parts for the first $77\frac{1}{2}^{\circ}$ degrees above 55° , and only 158 parts for the next $77\frac{1}{2}^{\circ}$, and the same difference obtained throughout, so that the expansion appeared to be in every part of the scale a gradually diminishing one in ascending. This difference however, Mr. D. shews to be probably only apparent, and to be owing to the circumstance first explained by M. de Luc, namely, that liquids do not expand quite equally for equal increments of heat, but in a ratio always increasing, though slowly, up to the boiling point of the liquid. Hence it follows that the thermometer does not measure quite correctly equal increments of heat, so that the expansion of the thermometrical fluid which corresponds with ten degrees (for example) on the top of the scale, really indicates a less actual addition of caloric, than the same number of degrees lower down in the scale, or nearer the freezing point. Therefore the first $77\frac{1}{2}^{\circ}$ degrees above 55° indicate an actual greater quantity of caloric than the second $77\frac{1}{2}^{\circ}$, which will account for part at least of the difference of actual expansion between 167 and 158. However, whilst the thermometer continues to be used as a perfect measure of equal portions of heat, the slight error thus induced must be allowed for.

In making experiments on the scale of expansion of any gas, the mode of drying with sulphuric acid, or any equally good way must be particularly observed in the colder temperatures, otherwise the consequent precipitation of moisture suspended in the gas would further embarrass and mislead the operator.

The experiments of M. Lussac^b coincide in a most satisfactory way with those of Mr. Dalton, and explain the reason of many of the anomalies in the results of the observations of other philosophers. By an ingenious apparatus M. Lussac found that 100 parts of common dry air at the freezing point, expanded by the heat of boiling water to 137.5 (taking the mean of six successive experiments, in which the greatest result was 137.61, and the lowest 137.40). This therefore would give an increase of 37.5 upon 100 for 180 degrees, or 0.209, nearly, upon 100 for every single degree of heat from 32° to 212° , supposing the thermometrical scale measured exactly equal increments of heat throughout.

Mr. Dalton's experiments gave an increase of 32.5 parts upon 100 for the 157 degrees between 55° and 212° which (extended to 180

degrees by simple proportion) would give an increase of 37.26 parts for 180° or .207 upon 100 for every single degree. But on account of the slowly increasing ratio of expansion of all fluids in proceeding towards the top of the scale of heat, it must follow that in bringing Mr. Dalton's experiments to a comparison with the other by extending the proportion from 55° down to 32° , it is thereby rated somewhat too low, which brings the two results still nearer. We may therefore take the following as an average (setting out of the question the small inequality of expansion, which is very seldom of any practical importance) namely, that 100 parts of common air gain .208 of bulk, or about $\frac{1}{488}$ by the addition of every degree of heat in all the ordinary temperatures at which experiments are made.

Both the above experimenters also found that the expansion of the other gasses was *the same as that of common air*, the slight differences being fairly attributed to the difficulty of conducting such nice experiments with perfect uniformity. Mr. Dalton found this result with hydrogen, carbonic acid, oxygen and nitrous gasses. M. Lussac with the above and with azot. With regard to the quantity of moisture in air, it appears that this only affects the uniformity of expansion when the temperature is so low that a part of it is precipitated, for when in complete solution in the air, it acts only like any other gas with regard to the circumstance of expansion.

In giving the volume of gasses they are generally understood in this country to be at the temperature of 60° , and therefore, from what has been above-mentioned, when above or below this point the necessary corrections should be made, allowing an increase of bulk, or *vice versa*, of .208 upon 100 parts for every degree of temperature in which it exceeds or falls short of this point. Thus a gas which occupies 30 cubic inches at 50° must be reckoned as equal to 30.624 at 60° , for 100 inches increase to 102.08 by 10 degrees of heat, and $100 : 102.08 :: 30 : 30.624$. Therefore also in operating in small quantities, such as a few cubic inches only, it will often happen that no very great practical error can arise from slight differences in temperature, since 2 cubic inches (or above an ounce in measure) of gas, will not expand by the addition of 2 degrees of heat quite $\frac{1}{100}$ of an inch, which is generally the least quantity indicated by any graduated vessel that chemists employ.

^a An. Chem. tom. 43, p. 137.

2. Of Pressure.

The next circumstance to be considered as affecting the volume of gasses is the pressure to which they are exposed, for, being elastic bodies, their bulk of course must be lessened by increased pressure, and *vice versa*. Gasses are almost always in different experiments exposed entirely or partially to the atmospheric pressure, modified by the artificial pressure arising from the height of the column of liquid by which they are confined.

The allowance to be made for pressure is perfectly simple, as it has been fully ascertained that the diminution of the bulk of a gas is in direct proportion to the compressing force. Thus if four cubic inches of air taken when the barometer is at 28 inches, is confined in a bent syphon tube closed at one end, and a column of 28 inches in height of mercury is poured in, the confined air will be diminished one half in bulk, and will be only 2 cubic inches, as it is now exposed to double the atmospheric pressure. Thus in every instance the bulk of the air is inversely as the pressure, and therefore, for example, a quantity of gas which occupies 100 cubic inches when the barometer is at 29.4 inches will be reduced to 98 inches, when the barometer is 30 inches, for 100 is to 98, inversely as 29.4 to 30, or directly as 30 : 29.4. No uniform standard of barometer is adopted in the register of chemical experiments as that of 60° is of the thermometer. In general however either 30 or 29.5 inches of the former are chosen, the average pressure being usually between these two numbers.

An artificial diminution of barometrical pressure is produced when a quantity of air is confined over a column of liquid, particularly mercury, the level of which within the jar is higher than the level of the mercury without. In this case the confined air occupies a larger space than it would, were the mercury within and without upon a level; because the weight of the air is not counterbalanced entirely by the elasticity of the air within the jar, but is partly counterbalanced by the weight of so much of the mercury within as is above the level of that without.

This circumstance if not attended to (which there is reason to suppose too often happens) is particularly liable to give a false idea of the nature of the gas in analysis as generally conducted. For supposing when the barometer is at 30. a quantity of gas is expelled from any mineral water (for example) by heat, and is received in an inverted jar full of mercury, and

standing over the same fluid, if the jar is 11 inches high, and only the 6 upper inches of mercury are displaced by the gas, the latter will then be superincumbent on a column of mercury 5 inches above the level of the fluid on the outside. It will then appear as if 6 inches of gas at 30 bar. have been procured, but this will exceed the true amount exactly in the proportion that 30 exceeds 30—5, or 25, the effect of the inner column of 5 inches of mercury being to counterpoise, and therefore to annihilate, an equal quantity of the atmospheric pressure, so that this will act on the inclosed gas with a force of 25 inches instead of 30; therefore the true amount of the gas will be only 5 inches instead of 6; for, 30 : 30—5 (25) :: 6 : 5. If now, in the usual course of analysis, some lime water is let up into the jar, the column of 5 inches of mercury will be displaced by the ascending lime-water, and the counteracting power to the atmospheric pressure will be now only that of 5 inches of watery fluid, instead of mercury, that is to say, it will be reduced to about one-fourteenth of its former power, (mercury being 14 times heavier than water) and hence the gas within will now contract to nearly its natural dimensions, and measure only about 5 inches. Thus therefore an apparent absorption of nearly one inch of the gas by the lime-water will be produced without a particle of air being really absorbed; and if at the same time a portion of carbonic acid is present (suppose one inch) the lime-water will become turbid and absorb this latter, and the result of the experiment will be 6 inches of gas, containing 2 of carbonic acid; instead of 5 inches, containing 1 of carbonic acid.

This source of error may be obviated in two ways, that is, either by sinking the jar so deep into the mercury that the fluid within shall be on the same level with that without, and the other by making the necessary allowance for the diminished pressure on the same principle that changes of common barometrical pressure are estimated. The former way is the best where it is practicable, being surer and not requiring the trouble of calculation. Where the mercurial bath has not a well deep enough to sink a tall jar into it, and where the gas cannot be conveniently transferred into a shorter jar, it will not be difficult to remove the jar holding the gas and mercury, into another jar full of the same fluid, and just large enough to admit the former to be sunk into it to the requisite depth. In operating with water instead of mercury the

pressure of a column of a few inches as already mentioned, will make so small a difference that it may be almost always disregarded.

But where it is impracticable to bring both surfaces to the same level the requisite correction must be made in the following manner: measure with a ruler the perpendicular height of the inner column of mercury above the level below, and find what proportion it bears to the height of the barometer at that time: then, as the whole barometrical height is to the same *minus* the height of the inner column; so is the number of cubic inches now occupied by the gas, to the true number under the entire atmospherical pressure. For example, if the height of the inner column be 7 inches, the barometer 28 inches, and the volume of the gas 84 cubic inches, then the true volume will be one-fourth less, or 63 cubic inches, (the inner pressure being equal to and counteracting one-fourth of the outer) for $28 : 28 - 7 (21) :: 84 : 63$.

Where this correction is made in jars accurately cylindrical and graduated, when the inner column of mercury is displaced by water, the height to which the latter will immediately rise above the level of the mercury which it has displaced, will be seen to be exactly in the same proportion to the whole height of the part of the jar first occupied by the gas, as the diminution of bulk is to the entire bulk of the gas when confined by the mercury.

In all these operations therefore it should always be remembered that when any gas is confined by an elevated column of mercury a diminution in bulk on throwing up any other liquid does not necessarily imply an absorption by that liquid till the requisite allowance has been made for this artificial expansion of the gas which the column of mercury produces.

We may conclude this article with one example of all the three corrections in estimating the volume of gasses. What will be the true volume of 75 cubic inches of gas confined in a jar by a column of mercury 6 inches above the level of the mercury without the jar, the barometer being 30 inches and the temperature 35° when brought to the standard of 29.5 bar. and 60° therm.?

First for the correction required by the different levels of the mercury without and within the jar we have the 75 inches reduced to 60, for $30 : 30 - 6 (24) :: 75 : 60$. Then the 60 cubic inches at 30 barometer when brought to the required pressure of 29.5 will be enlarged to 61.01, for $29.5 : 30 :: 60 : 61.01$.

Lastly, for the 25 degrees of increased temperature, as 100 parts gain .208 by each degree they would gain 5.2 for the 25 degrees, and hence the 60.01 would gain 3.17; for $100 : 5.2 :: 61.01 : 3.17$. Therefore the 61.01 cubic inches at 35° will be increased to 64.18 cubic inches at 60° , so that the true volume of the 75 cubic inches under all the circumstances above mentioned, will be 64.18 at 29.5 barometer and 60° thermometer.

The methods of managing experiments on gaseous bodies will be described in the *Appendix of Apparatus*, and the tests of the particular gasses and the methods of analysis will be found under the respective articles.

GASSEOUS OXYD OF AZOT. See **NITROUS OXYD.**

GASSEOUS OXYD OF CARBON. See **CARBONOUS OXYD.**

GAS-HOLDER. An article of chemical apparatus. (*See the Appendix.*)

GASTRIC JUICE.

This is a thin limpid watery fluid secreted into the stomach of all animals and appears to be the chief agent in the conversion of food into nutritive matter by the process of digestion.

The analysis of this fluid has excited much of the attention of several physiologists as being closely connected with all attempts to explain the important process of digestion, but with no other result than to shew that mere chemical reasoning, in the present state of knowledge, is entirely inadequate to the purpose, the gastric fluid shewing in analysis no important or peculiar substance which can at all throw any light on the cause of its remarkable properties.

There are several methods of collecting this juice in greater or less purity. The simplest is to keep the animal for some time fasting, when on killing it a considerable quantity of gastric juice will be found in the stomach, and which probably is the immediate cause of the sensation of hunger. In this manner Spallanzani collected a quart of the juice from the stomach of a sheep kept fasting for two days before it was killed. Another method is to excite vomiting in an animal kept for some time fasting, when the liquor ejected will be chiefly gastric juice, but mixed with a little bile and saliva.

Another method used by Reaumur and Spallanzani is to make the animal swallow small dry sponges loosely enclosed in perforated hollow metallic balls to prevent their being squeezed by the muscular action of the stomach. When these balls are ejected after being some

hours in the stomach the sponges are soaked with gastric juice of considerable purity.

Notwithstanding the uniformity in the effects of gastric juice on animal and vegetable matter the chemical analysis shews a considerable variety in the number and proportion of the ingredients, but on the whole these are in very small proportion to the mere watery part. Much of this variety may depend on casual admixture with the other animal juices, and the small portion of food still remaining in the stomach, which probably no endurable length of fasting will entirely remove, and much certainly depends on the general food of the animal, that is, whether habitually carnivorous or herbivorous, or made so contrary to nature by artificial habit. The only constant ingredients of gastric juice appear to be muriatic acid, soda, ammonia, and phosphoric acid in their different combinations, and a small but never absent portion of animal extractive matter, the whole dissolved in a very large portion of water. It very frequently happens that this liquor shews marks of acidity, but this property is not constant, and there is considerable reason to suppose that this may arise from casual admixture with some acid arising from the food itself.

This liquid is remarkable for two properties which it possesses to an extreme degree, and which seem necessary to the function of digestion, but nevertheless cannot be accounted for on any of the known qualities of its ingredients: these are its powers of *coagulating* all coagulable liquids, and its *antiseptic* power, or that of preventing the putrid fermentation of animal matter, or correcting it when formed.

Experiments on this subject belong more to physiology than pure chemistry, but it may be observed that the power of coagulation of substances in contact with gastric juice also seems to reside in the stomach itself, and is familiarly known by the use of the common *rennet* for separating the curd from milk in cheese-making, which is an infusion of the digesting stomach of the calf in salted water. The antiseptic power of the gastric juice is strikingly shewn in those animals (the vulture and the weasel for example) who readily devour their food in the most disgusting state of putrefaction, and in whom it is found to lose most of its putrescency after remaining a short time in their stomach. The gastric juice has also a similar power out of the body.

The actual analysis of the gastric juice of the sheep is thus given by Macquart. ^a

Twenty ounces yielded 77 grains of solid matter, the rest being mere water.—These 77 grains consisted of

	grs.
Phosphoric acid - - - - -	17
Phosphat of lime - - - - -	5
Muriat of ammonia - - - - -	14
Muriat of soda - - - - -	29
Albumen - - - - -	10
Resinous and extractive matter	2
	77

Other analyses shew a considerable variation in the ingredients, which are of themselves utterly incapable of explaining the effects of the liquor, all of them find the common salt to be in the largest quantity, and phosphoric acid either naked or in combination to be constantly present.

GAZOMETER. An article of Chemical Apparatus. (*See the Appendix.*)

GELATIN, or ANIMAL JELLY. *Gallerte Thierische*, Germ.

This is a most abundant principle in a vast variety of the parts of animals, and appears to be one of the great elementary constituents of animal organization. Scarcely any organ is without it, but it is most abundantly contained in skin, in most of the soft and white parts, in bone, and the hard bony horns, in membrane of all kinds, in the blood in small quantity, and also in small proportion as the natural cement of many of the shells.

From all of these substances gelatin is extracted simply by boiling in water for a greater or less time, according to the hardness or toughness of the substance employed. This watery solution is transparent and colourless, or nearly so, and when gently evaporated to a small bulk and suffered to cool it *gelatinizes*, or assumes the consistence of cohering, extremely flexible and mobile, soft, tremulous *jelly*, such as is known to every one as prepared for the table.

By further evaporation, the watery solution of gelatin may be rendered hard and brittle, in a degree partly determined by the degree of evaporation, and partly by the original gelatinizing force of the substance that yields it. In this state it forms the solid carpenter's *glue*, or of less stiffness the different kinds of *size* used as cements in so many of the arts. The preparation of these will be described after mentioning the chemical properties common to pure gelatin of every description.

^a *Phyf. tom. 2. Johnson's Animal Chem.*

Chemistry is indebted to Mr. Hatchett for a most valuable series of experiments on gelatin, and substances yielding it, in which many important and characteristic chemical distinctions are pointed out.^a

In all cases this substance when pure is absolutely insipid, transparent, and nearly colourless, or only with a shade of yellow. It is also without smell. Dry gelatin when thrown into water gradually absorbs it, swells to many times its original bulk, softens, and becomes extremely elastic. It does not however dissolve therein as long as it remains cold, but if taken out and put in a very warm dry air, it again shrinks, and returns nearly to its former consistence. But if heat is applied to gelatin thus swelled by soaking and immersed in more water, it very speedily dissolves, forming a solution exactly resembling in chemical qualities the original liquor from which the dry gelatin was prepared, of the same density, and therefore again gelatinous by cooling. It is therefore an inherent and also a very characteristic property of gelatin to be soluble in water and recoverable from the solution by evaporation unaltered, for an indefinite number of times, even after long application of a boiling heat. In this it essentially differs from the solution of albumen, which coagulates by heat and does not again return to its soluble state.

All kinds of gelatin are soluble in all the acids, and with the same comparative readiness with which they yield to the action of water. The nitric acid acts with particular energy on gelatin, even when considerably dilute and in the cold, and this is a very convenient method of separating it from the condensed albumen which often exists in natural combination with it. Thus if cartilage is immersed in weak nitric acid and allowed to remain in for a day or two, all the gelatin and any earthy matter which it may contain gradually dissolves, leaving a firmer substance retaining the original shape of the cartilage, which the acid when dilute will not touch. The nitric solution of gelatin (of isinglass for example) is of a pale yellow deepening by evaporation. When much concentrated the acid which at first appears to act merely as a solvent, is decomposed by the gelatin, and nitrous gas is given out, sometimes attended with sparks or flame. This mutual decomposition of nitric acid and gelatin produces also a quantity of the oxalic and malic acids, which are to be detected in the liquor if the concentration has not proceeded so far as again to decompose these new products.

The acid solutions of gelatin give no precipitate when saturated with any of the alkalies or earths.

The muriatic acid dissolves gelatin in the cold with great ease, and like the nitric separates it from the dense albumen of organized bodies with which it is naturally combined. The muriatic solution may be kept unchanged for many months.

The caustic fixed alkalies dissolve gelatin with great ease, forming a brownish viscid substance, but no ammonia is given out during the solution. This viscid alkaline solution, according to Mr. Hatchett, does not possess the properties of soap, for it does not form a permanent lather when shaken with water, nor when saturated with acid does it afford any precipitate. This Mr. H. gives as a very characteristic property, distinguishing pure gelatin from albumen, fibrin, and most other soft parts of animals, all of which latter form a true soap with alkalies, that curdles and precipitates on saturation with an acid.

Gelatin is insoluble in pure alcohol, and when this spirit is poured into a watery solution of gelatin, the mixture becomes milky and part of its gelatin separates (as takes place with the vegetable mucilages and alcohol) but unless a very large quantity of spirit is added the mixture again becomes clear.

Gelatin when hard and dry will keep for a great length of time without change, but when liquid or in the thin gelatinous state, it very soon putrefies, first growing sour by the generation of acetic acid, then mouldy and fetid, and at last exhaling ammonia.

When dry gelatin is strongly heated, it curls up and becomes puffy, and yields an oily ammoniacal liquor, like all other soft parts of animals. In close vessels it leaves at last a bulky soft coal, the proportion of which according to Mr. Hatchett, is 56 grains from 500 of isinglass. This by incineration in open air burns away entirely, except 1.5 gr. of earthy residue, which appears to be the phosphates of soda and lime. The quantity of earthy and saline matter therefore is extremely small compared with that of the other soft parts.

The same chemist has also observed a kind of artificial conversion of condensed albumen into gelatin by long digestion in dilute nitric acid, the albumen thereby becoming perfectly soluble in water, and forming a gelatinizing solution when reduced by evaporation.

The extent of the *gelatinizing power* of the pure gellies, or the power of uniting with so

^a Phil. Transf. vol. 90.

much water as still to remain a stiff cohering mass when cold, is shewn by the experiments of Dr. Bostock,* who found that when water contained no more than $\frac{1}{1000}$ of its weight of isinglass it still compleatly stiffened by cooling, and even when only $\frac{1}{500}$, the solution was evidently gelatinous when cold, though not absolutely concrete.

The most singular combination of gelatin and that which is most useful as a chemical test is with tan. If a solution of gelatin, of glue or isinglass for example, is added to an infusion of oak bark, galls, catechu, or any other vegetable that contains the tanning principle a copious white precipitate separates, which when the respective liquors are concentrated may be collected by the fingers with great ease, and forms a singular grey ductile mass, smelling like tanned leather, and which dries into a dark brown brittle mass of the appearance of resin, insoluble in water, and incapable of putrefaction. This combination, which appears to be chemically the same as highly tanned leather, will be further noticed under the article TAN.

The power of infusion of tan as a test of gelatin is very extensive. Dr. Bostock found a copious and immediate precipitate on adding a moderately strong infusion of galls to water holding only $\frac{1}{1000}$ of isinglass, and a very considerable precipitate when the gelatin was only $\frac{1}{5000}$.

The solutions of albumen also give a precipitate with tan, but not till after standing together some hours, and therefore when used as a test, an immediate precipitate with tan, may be considered as a pretty certain indication of gelatin.

The nitro-muriat of tin also produces a white precipitate with gelatin, but unless the solution of the latter is pretty strong, the effect is only a white cloud, after some hours standing. Nearly the same effect is produced with the solutions of albumen.

The difference in the degree of viscosity and tenacity of the varieties of gelatin, is as Mr. Hatchett observes, an inherent quality, and not caused by the degree of mere inspissation, otherwise when each variety was perfectly dry, they would each make a glue or cement of exactly the same degree of tenacity, which is known not to be the case. On the contrary the tenacity depends partly on the age of the animal, the old giving a much stronger glue, *ceteris paribus*, than the young: and partly on the substances that furnish it, the glue from the skin

being much stronger than the solid gelatin from the bones, sinews, or any other part. In proportion as the glue is more adhesive, it becomes less easily soluble in water, and absorbs a larger portion before it comes to the state of tremulous gelly. Mr. Hatchett also found that the force of adhesion of the glue from skin was generally proportionate to the toughness of the skin, the soft flexible skins yielding a thinner gelatin than the hard bony skins, and with much more ease.

GLUE, such as is made by the carpenters, appears to be made in greater perfection in this than in any other country, if we may judge of the estimation in which English glue is held abroad. The minute circumstances of the operation which give a superiority of the article of one manufacturer over another cannot be readily ascertained, but the following is given by Mr. Clennel as the general mode of manufacture. " Glue is an inspissated gelly, made " of the parings of hides or horns of any kind, " the pelts obtained from furriers, the hoofs " and ears of horses, oxen, calves, sheep, &c. " These are first digested in lime-water, to " cleanse them from grease or dirt, they are " then steeped in clean water with frequent " stirring, afterwards laid in a heap and the " water pressed out. They are then boiled in " a large brass cauldron with clean water skim- " ming off the dirt as it rises, and it is further " cleansed by putting in, after the whole is dis- " solved, a little melted alum or lime finely " powdered. The skimming is continued for " some time, after which the mass is strained " through baskets, and suffered to settle that " the remaining impurities may subside. It is " then poured gently into the kettle again, and " further evaporated by boiling and skimming " till it becomes of a clear darkish brown " colour. When it is thought to be strong " enough it is poured into frames or moulds " about six feet long, one broad, and two deep, " where it gradually hardens as it cools, and " is cut out when cold by a spade into square " cakes. Each of these is placed in a sort of " wooden box open in three divisions to the " back, in this the glue while yet soft is cut " into three slices by an instrument like a bow, " with a brass wire for its string. The slices " are then taken out into the open air, and " dried on a kind of coarse net-work, fastened " in moveable sheds four feet square, which are " placed in rows in the glue-maker's field. " When perfectly dry and hard it is fit for " sale. That is thought to be the best glue

* Edinbg. Med. and Phys. Journ. No. 2.

* Monthly Mag. for 1802, p. 5.

" which swells considerably without melting by
 " three or four days immersion in cold water,
 " and recovers its former dimensions and pro-
 " perties by drying. Glue that has got frost
 " or that looks thick and black, should be
 " melted over again. To know good from bad
 " glue the purchaser should hold it between his
 " eye and the light, and if it appears of a
 " strong dark colour, and free from cloudy or
 " black spots, the article is good."

To this distinct and apparently accurate account of glue-making, may be added some experiments by Pelletier,* on a glue from bones, made in France by a M. Grenier, from the raspings and trimmings of ivory, the refuse pieces and shavings of the button-mould makers, and other kinds of hard bone, that cannot be turned to account in entire manufacture. Six pounds of button-mould shavings were put into a copper boiler with 24 quarts of water, and first let to soak for two hours in the cold. The fire was then kindled and the liquor slowly brought to boiling, and kept at this heat for nine hours. After standing a night 14 quarts of clear gelatinous liquor were drawn off by a syphon, and two quarts more were obtained by pressing the residue. This was duly evaporated without addition, and when of the proper consistence was allowed to subside for half an hour, when it became firm enough to be cut into cakes, which being then hung up for a fortnight in a barn yielded about 15 ounces of solid glue, or rather less than a sixth of the weight of the bone shavings originally used. A similar experiment made with ivory-turnings yielded nearly the same proportion of glue. The gelly from these clean white bones is at first very transparent and with little colour, but when concentrated by evaporation it always deepens in colour, but if well made still remains transparent. A piece of this glue put into cold water swelled, as happens with common good glue, and in 24 hours had absorbed 15 times its weight of water, but without dissolving, and by again drying in the air, it returned to its original bulk and weight. It appears that at Paris there are three sorts of glue commonly sold, the best is that which is imported from this country, and is of a deep red, the next in value is the Flemish, which is whitish and transparent, and the most ordinary glue of the country is black and opaque.

In using glue, the carpenters first break it and cover it with cold water, and let it stand for about twenty-four hours, by which, as al-

ready mentioned, it swells to many times its original bulk, and absorbs a large quantity of this fluid, after which the soaked pieces are melted, without more water, over a slow fire, and kept simmering for about a quarter of an hour with frequent stirring and are then cooled. It is now a firm gelly, of such a consistence, as very readily to be cut by any instrument, but too stiff to be tremulous. When wanted to be used, it is merely warmed which renders it sufficiently fluid to be spread over the surface of the wood with a stiff brush. Wood joined by glue requires from one to three days to be perfectly cemented, which is known by the hardness of the portion that remains on the outside of the joining, and the force of cohesion of the best glue is such, that boards as thick as any commonly used in furniture carpentry will full as readily give way by violence in any other part of the substance as at the joining. Glued boards will not set in a freezing temperature, the stiffening being owing to the evaporation of the superfluous water of the glue which is prevented by great cold.

* * *

A variety of gelatinous cements of less firmness than common glue, and known by the general term of *Size*, are made for the use of the paper-hangers, gilders, bookbinders, house-painters in distemper, and many other trades, by boiling down in water the clippings of parchment, glove-leather, fish-skin, and many other kinds of skin and animal membrane. These are used either alone or mixed with vegetable tenacious substances, such as flour-paste, gum-arabic and tragacanth, and the like. The preparation of these jellies is perfectly simple, the substance used (parchment shreds for example) being simply dissolved in water by boiling, strained and evaporated to a due consistence. Eel-skins and the skins of other fishes make a cement which is much valued for its transparency and tenacity. The only species of gelatin of this kind used in the arts which requires further notice is

ISINGLASS.

This is a thin, flexible, tough, whitish membrane, in the form of irregular shreds or clippings loosely coiled up, and of different degrees of fineness and flexibility, which is procured from several parts of the entrails of several fishes, with scarcely any artificial preparation than that of extracting, cleansing, and drying.

The finest kind of isinglass is that which has the longest *staple* as it is called, and which is

* Mem. de Pelletier, tom. 2.

the thinnest and most flexible. The preparation of isinglass is almost peculiar to Russia,^d and is made in all places on the vast rivers of this mighty empire, where the large sturgeon and other fishes of this genus are caught, as on the Dnieper, the Don towards the Caspian Sea, the Volga, Oby, Irtysh, and other Asiatico-Russian rivers. The best isinglass is that which is prepared from the sturgeon. The membranes which, when dried, form isinglass, are various extensions and processes of the peritoneum, but more particularly the air-bladder, or sounds, which is very large in these fishes. The sounds when taken out of the fish are first washed with cold water, and exposed a little to stiffen in the air. The outer skin is then peeled off and thrown away. The remainder is simply cut out and loosely twisted into rolls according to the intended size of the staple, which are pegged down on boards, and hung up on lines to dry. No other preparation is used. An inferior kind of cake-isinglass is made by taking all the clean shreds of the twisted sort, putting them in a flat metal-pan with a very little water, and heating just enough to make a cohering mass. This is afterwards dried. It would be tedious to enumerate the minute varieties of isinglass or fish gelatin.

Good isinglass is esteemed the finest and purest specimen of animal gelatin. It is entirely without taste or smell, when soaked in water it swells, softens, and if held up to the light is agreeably opalescent to the eye. It readily and totally dissolves in warm water, forming the clearest and most colourless of all the known jellies. The finer sorts are much too valuable to be used for the ordinary purposes of a size or cement, but are principally employed in confectionary, in clarifying wines, and other purposes of the table.

When the jelly of isinglass is much concentrated by evaporation, it forms a delicate cement for joining glass, &c. for which its great transparency and freedom from colour render it highly valuable. The coarser sort of fish-glue cake, or that which consists of refuse bits of isinglass, brought to a cohering mass by water, is often used for the same purposes as common glue. This when foul and blackened is bleached by exposure to the vapour of sulphur,^e which, on account of the loose fibrous texture is able to penetrate it sufficiently, an effect which could not take place with the solid cakes of common glue.

ANIMAL MUCILAGE.

In some parts of the body of man and different animals is found a somewhat clammy, insipid, whitish or often colourless liquor, uncoagulable by heat, but leaving after a gentle evaporation to dryness a small proportion of slimy tenacious matter, much resembling gelatin in appearance, and in being equally again soluble in water. The saliva is perhaps the best example of simple animal mucilage in the human body, but it is found more copiously in other animals, as for example, in the oyster, and many marine inhabitants.

Animal mucus or mucilage differs however from gelatin in being readily soluble in cold water, and especially in having no proper gelatinizing power, that is to say, a hot solution does not stiffen, or approach apparently more to the solid state by cooling, but its degree of viscosity depends simply on the proportion of water in the solution without regard to temperature.

Mr. Hatchett considers mucus, however, as a species of gelatin the lowest in the cohesive power, or at one extremity of the scale of tenacity, at the other extremity of which is the stiffest glue from condensed skin.

But Dr. Bostock has given the following distinctive marks which certainly establish as clear a difference between mucus and gelatin as exists between many other substances strongly resembling each other, but which have been allowed a separate place. The mucus of an oyster was detached by agitation in cold water for a few minutes, when the fluid was filtered and appeared slightly opaque and gelatinous. By evaporation it appeared that it had dissolved about $\frac{1}{50}$ of its weight of animal matter. A quantity of this diluted with as much water was tried with the following reagents: a solution of corrosive mercurial muriat produced no effect; the infusion of tan (from galls) after some time produced a slight turbidness, and at length a small quantity of a precipitate. The aqua lithargyri acetati (or vinegar saturated with litharge at a boiling heat) gave an immediate opacity, and, after some time, a dense white precipitate.

The first of these tests, the mercurial solution, is found to precipitate albumen only, and as no effect was here produced, it shews the absence of this principle. The solution of tan occasioned only a very slight opacity, but by previous experiments it was found that a solu-

^d Tooke's Russian Empire. Also Jackson in Phil. Transf. vol. lxiii.

^e Pelletier.

tion of true gelatin in $\frac{1}{100}$ times its weight of water, or equally dilute with the present solution, would have given an immediate and copious precipitate with tan, a character sufficiently discriminative. On the other hand gelatin will not be precipitated by acetited litharge, whereas mucus is abundantly affected by this test. These differences, therefore, together with the absence of the gelatinizing property, will, for the present, entitle us to consider mucus as a distinct animal principle.

GELBERDE. See YELLOW EARTH.

GEMS. Gems or precious stones form a class of earthy minerals very distinguishable in commerce by their superior price, but of which it is not easy to give a scientific definition. That furnished by Boetius de Boot^a is, perhaps, upon the whole, the best which is to be found. "Lapis" says he, "alius a Natura magnus, alius parvus producitur; parvus alius rarus inventu, alius frequens. Rarus alius durus, alius mollis. Durus alius pulcher aspectuque gratus, alius turpis. Pulcher Gemmae nomen meretur. Erit itaque gemma lapis parvus, rarus, durus, et pulcher, a Naturâ procreatus." *Nature forms some stones large and others small; of the small, some are of rare occurrence, others are common; of the rare, some are hard, others are soft; of the hard, some are beautiful and pleasant to the sight, others are mean. The beautiful merit the name of Gems. The word gem therefore signifies a natural stone of small size, rare, hard, and beautiful.*

The ancients seem to have made a difference between precious stones and gems, comprehending under the former term those hard and beautiful, but for the most part uncrystallized stones, such as agate, carnelian, onyx, chalcedony, &c. upon which they were accustomed to engrave, restricting the word gem to those stones which, on account of their minuteness, extreme hardness, and brilliant lustre, were worn in rings and other ornaments, either in the state in which nature presents them, or, at most, after being cut and polished. Some stones, however, such as the topaz and amethyst, being commoner and in larger pieces than most of the other gems, held a kind of middle rank between these and the precious stones, being sometimes employed as materials to engrave upon, and sometimes used plain for necklaces, rings, &c.

Bergman in his excellent essay on the earth of gems has shown, contrary to the general opinion of his day, that the hardness and crystalline texture of the gems is not owing to

their consisting almost entirely of vitrifiable earth or silice; since many of the gems, especially those called oriental, appear from analysis to contain a much larger quantity of alumine than of silice. On the other hand, however, this able chemist himself is deceived when he labours to shew that all the most perfect gems, including the diamond, are indebted for their hardness, exceeding specific gravity and lustre to the presence of alumine in their composition; it being now fully ascertained that the diamond when pure is wholly combustible, and therefore contains no earth whatever.

The particular gems are described at large in their proper places; we shall therefore only give a list of them here, arranging them in four classes, according to the relative estimation in which when perfect they are held by jewellers; premising, however, that this order is subject to some variations from the casual plenty or scarcity of any particular kind, and from the caprice of fashion.

The diamond and the oriental ruby constitute the first class. Of these, a very small diamond is more valuable than a ruby of equal weight; but rubies of ten carats or more being much rarer than diamonds of equal weight bear a somewhat higher price in the market. The second class of gems contains the emerald, star-stone, oriental girasol, sapphire, spinel and balais rubies, oriental topaz, oriental amethyst, and noble opal. In the third rank are found the jargoon, cat's-eye, oriental chrysolite, hyacinth, and peridot. Those in the fourth and lowest class are often engraved upon, and form the most valuable seal-stones; they are the beryl or aqua-marine, Brazilian topaz, Saxon topaz, Sirian garnet, Bohemian garnet, and European amethyst.

GEMS ARTIFICIAL. See GLASS (coloured.)

GILDING, art of. *L'Art de Dorer*, Fr. *Die Kunst zu Vergolden*, Germ.

The art of gilding or of laying a thin superficial coating of gold on wood, metal and other substances has been long practised, and highly esteemed both for its utility and the splendid effect which it produces. Gold, from the extreme beauty of its colour, and from the length of time during which it may be exposed to the action of the air without tarnishing, is perhaps the most valuable of all substances for the purpose of decoration; but on account of its dearth and weight it can very seldom be employed in substance, and its ornamental use would be limited indeed if it was not at the same time

^a De Gemmis, p. 12.

the most extensible of all substances: so that a given weight of gold, notwithstanding its high specific gravity, may by beating be made to cover a larger surface than an equal quantity of any other body. Among the ancients, the Romans, and among the moderns, the French have been remarkable for their large and profuse consumption of gold: not only the temples, theatres, and other public buildings being adorned with gilding, but even the private houses of the wealthier classes.

The materials of gilding, or rather the different states in which gold is used for this purpose, are the following: leaf-gold, of different thicknesses and formed either of the pure metal, or of an alloy of this with silver, amalgam of gold, and gold powder. The leaf-gold is procured by the gilder from the gold-beater, for an account of which we shall refer the reader to the article GOLD; but the other two substances being prepared by the gilder himself may be with propriety described here. The amalgam of gold is made by heating in a clean crucible some pure quicksilver, and when it is nearly boiling adding to it about a sixth of its weight of fine gold in thin plates heated red hot; the mixture after being kept hot for a few minutes becomes of a perfectly homogeneous consistence, and may then be allowed to cool: when cold it is to be put in a piece of soft leather, and by gradual pressure the fluid part of the amalgam consisting almost wholly of mercury may be forced through the pores of the leather, while the gold combined with about twice its weight of mercury will remain behind forming a yellowish silvery mass of the consistence of soft butter. This after being bruised in a mortar, or shaken in a strong vial with repeated portions of salt and water till the water ceases to be fouled by it, is fit for use, and may be kept for any length of time without injury in a corked vial. It is of essential importance that the materials of this amalgam, and especially the mercury, should be perfectly pure, as the least portion of lead or bismuth would very materially injure the beauty of the gilding by deteriorating the colour of the gold and filling it with black specks; on this account no mercury ought to be employed that has not been procured from distillation of the red precipitate (nitrous red oxyd of mercury) either alone or mixed with a little charcoal powder.

Gold powder is prepared in three different ways. The first and simplest is to put into a glass or earthen mortar some gold-leaf with a little honey or thick gum-water, and grind the

mixture for a considerable time, till the gold is reduced to extremely minute fragments; when this is done a little warm water will wash out the honey or gum, leaving the gold behind in a flaky pulverulent state. A less tedious and more effectual way of comminuting the gold is to dissolve it in nitro-muriatic acid and then precipitate it by a piece of copper: the precipitate after being digested in distilled vinegar and then well washed in water and dried, is in the form of a very fine powder, and both works better and is easier to burnish than the ground leaf-gold. The finest ground gold however is produced by heating very gradually the gold-amalgam in an open earthen vessel, and continuing the fire till the whole of the mercury is evaporated, taking care that the amalgam shall be constantly stirred with a glass rod or tobacco-pipe, in order to prevent the particles of gold from adhering as the mercury flies off. When the mercury is completely evaporated the residual gold being then ground in a Wedgewood ware mortar with a little water, and afterwards dried, is fit for use.

Gilding is performed either with or without the application of heat. By the first of these methods those substances are gilt which are not liable to alteration by exposure to a moderate heat, such as metals and sometimes glass and porcelain: the second method is practised with those substances, such as wood, paper, leather, silk, lacquered and japanned ware, &c. which would be injured, and even destroyed at the temperature requisite for gilding the former. The last of these methods being the simplest shall be first described; and we shall begin with the art of gilding on wood.

There are two methods of gilding on wood, namely, oil-gilding and burnished gilding. Oil-gilding is thus performed. The wood must first be covered or primed with two or three coatings of boiled linseed-oil and white-lead, in order to fill up the pores and conceal the irregularities of the surface occasioned by the veins in the wood. When the priming is quite dry a thin coat of gold-size must be laid on. This is prepared by grinding together some strongly calcined red ochre with the thickest drying oil that can be procured, and the older the better: that it may work freely it is to be mixed, previously to being used, with a little oil of turpentine till it is brought to a proper consistence. If the gold-size is good it will be sufficiently dry in twelve hours, more or less, to allow the artist to proceed to the last part of the process, which is the application of the

gold. For this purpose a leaf of gold is spread on the cushion (formed by a few folds of flannel secured on a piece of wood about eight inches square by a tight covering of leather), and is cut into strips of a proper size, by a blunt pallet-knife; each strip being then taken up on the point of a fine brush is applied to the part intended to be gilded, and is then gently pressed down by a ball of soft cotton; the gold immediately adheres to the sticky surface of the size, and after a few minutes the dexterous application of a large camel's-hair brush sweeps away the loose particles of the gold-leaf without disturbing the rest. In a day or two the size will be compleatly dried, and the operation is finished. The advantages of this method of gilding are that it is very simple, very durable, not readily injured by changes of weather even when exposed to the open air, and when soiled it may be cleaned by a little warm water and a soft brush: its disadvantage is that it cannot be burnished, and therefore wants the high lustre produced by the next method. Its chief employment is in out-door work.

Burnished gilding, or gilding in distemper, is thus performed. The surface to be gilt must first be carefully covered with strong size made by boiling down pieces of white leather, or clippings of parchment till they are reduced to a stiff jelly; this coating being dried, eight or ten more must be applied, consisting of the same size mixed with fine Paris-plaster, or washed chalk; when a sufficient number of layers have been put on, varying according to the nature of the work, and the whole is become quite dry, a moderately thick layer must be applied composed of size and bole, or yellow ochre: while this last is yet moist the gold leaf is to be put on in the usual manner; it will immediately adhere on being pressed with the cotton ball, and before the size is become perfectly dry those parts which are intended to be the most brilliant are to be carefully burnished with an agate or dog's tooth. In order to save the labour of burnishing it is a common but bad practice, slightly to burnish the brilliant parts, and to deaden the rest by drawing over them a brush dipped in size: the required contrast between the polished and unpolished gold is indeed thus obtained, but the general effect is greatly inferior to that produced in the regular way, and the smallest drop of water falling on the sized part occasions a stain. This kind of gilding can only be applied on in-door work, as rain, and even a considerable degree of damp-

ness will cause the gold to peel off. When dirty it may be cleaned with a soft brush and hot spirit of wine, or oil of turpentine. It is chiefly used on picture frames, mouldings, and stucco.

Letters written on vellum or paper are gilded in three ways: in the first, a little size is mixed with the ink, and the letters are written as usual; when they are dry a slight degree of stickiness is produced by breathing on them, upon which the gold leaf is immediately applied, and by a little pressure may be made to adhere with sufficient firmness: in the second method some white lead or chalk is ground up with strong size, and the letters are made with this by means of a brush: when the mixture is almost dry the gold leaf may be laid on and afterwards burnished: the last method is to mix up some gold powder with size, and make the letters of this by means of a brush. The edges of the leaves of books are gilded while in the binder's press by first applying a composition formed of four parts of Armenian bole and one of sugar-candy ground together to a proper consistence, and laying it on by a brush with white of egg: this coating when nearly dry is smoothed by the burnisher, it is then slightly moistened with clean water, and the gold leaf applied and afterwards burnished. In order to impress the gilt figures on the leather covers of books, the leather is first dusted over with very fine powdered rosin or mastich, then the iron tool by which the figure is made is moderately heated, and pressed down upon a piece of leaf-gold, which slightly adheres to it, being then immediately applied to the surface of the leather with a certain force, the tool at the same time makes an impression, and melts the mastich which lies between the heated iron and the leather; in consequence of this the gold with which the face of the tool is covered is made to adhere to the leather, so that on removing the tool a gilded impression of it remains behind.

Drinking glasses and other utensils of this material are sometimes, especially in Germany, gilt on their edges: this is done in two ways, either by a simple adhesive varnish, or by means of fire. The varnish is prepared by dissolving in drying linseed oil a quantity of gum anime, or still better, of clear amber equal in weight to the oil; a very drying and adhesive varnish is thus prepared, which being diluted with a proper quantity of oil of turpentine is to be applied as thin as possible to those parts of the glass which are to be gilded; when this is dry, which will be in about a day,

the glass is to be placed by the fire-side, or in a stove till it is so warm as almost to burn the fingers when handled; at this temperature the varnish will become glutinous, and a piece of leaf gold applied in the usual way will immediately adhere; when the gilding is thus put on and before it is grown quite cold it may be burnished, taking care only to interpose a piece of very thin paper between the gold and the burnisher. If the varnish is very good this is the best method of gilding glass as the gold is thus fixed on more evenly than in any other way: it often happens however when the varnish is but indifferent that by repeated washing the gold soon wears off: on this account the practice of burning in is sometimes had recourse to. For this purpose some powder-gold is tempered with gum-water and borax, and in this state applied to the clean surface of the glass with a fine camel's hair pencil: when quite dry the glass is put into a stove heated to about the temperature of an annealing oven, the gum burns off and the borax by vitrefying cements the gold with great firmness to the glass; after which it may be burnished. The gilding upon porcelain is in like manner fixed by fire and borax; and this kind of ware being neither transparent nor liable to soften and thus injure its form in a low red heat, is free from the risk and injury that the finer and more fusible kinds of glass are apt to sustain from such treatment.

All the methods of gilding hitherto described resemble each other by being accomplished by means of some adhesive medium; this, however, is not the case with gilding upon metals, the gold is brought into immediate contact with the other metal, and they both remain firmly united merely by the attraction of adhesion subsisting between them. The simplest of all the kinds of gilding on metal, and which strikingly demonstrates the power of the affinity of adhesion is one that is sometimes practised on plane surfaces of copper and iron with considerable success. The metal being previously polished and quite clean is heated to about the temperature of melted lead, and covered with a double layer of gold leaf: by the cautious application of a blood stone burnisher applied gently at first, and increasing the force of the pressure by degrees the surfaces of gold and copper are brought to touch each other in almost every point, and then adhere with a force proportioned to the compleatness of the contact. The first layer being thus burnished down a second is made to adhere in the same

manner, and sometimes a third, if the gilding is intended to be very solid. The objection to this method of gilding is its tediousness, and the almost impossibility of using a sufficient pressure without injuring the evenness of the gilded surface: where these objections do not apply there cannot be a more effectual mode of gilding as is evident from the manufacture of gilt silver or copper wire. The bar before it is committed to the wire-drawer, is plated with gold by having several leaves of gold successively burnished down upon it, and being then subjected to the strong compression that takes place in wire-drawing, the gold and the other metal become so perfectly united as to form in a manner but one substance.

The most usual method of covering the surface of a metal with gold is by means of an amalgam, or as it is technically called *water-gilding*. If the metal to be gilt is silver, the best way of proceeding is first to soak it in warm dilute muriatic acid that the surface may be rendered perfectly clean; it must then be washed in clean water changed two or three times to get rid of the whole of the acid: being afterwards dried and made moderately warm a little gold-amalgam also warm is to be carefully and evenly spread upon the silver to which it will immediately adhere: when this is compleated the piece is placed upon a convenient support over a clear charcoal fire, and while the mercury is evaporating if any specks or places appear that have escaped the amalgam a small piece is to be laid on and spread with a brush to supply the deficiency, without removing the article from the fire. After a time the whole of the mercury will be driven off, and the piece after cooling being accurately examined will be found to be entirely covered with a thin coating of pale dull gold. The small roughnesses and loosely adhering particles are now to be removed with a scratch brush, which is made of some exceedingly fine brass-wire bound together into a tuft; by this the surface is rendered perfectly smooth and bright, but it still remains of a pale yellow colour: this defect is next removed by warming the piece and smearing it over with gilder's wax, a composition of bees-wax, red ochre, verdigris, and green vitriol or alum. The wax being burnt off over a charcoal fire, and the piece quenched in urine the colour of the gilding will be found to be much heightened; if it is not sufficiently so by the first application a succeeding one will compleat the desired effect; after which the work may be burnished or not

according to the taste of the artist. Instead of the common gilder's wax a mixture of equal parts of nitre, sal ammoniac, green vitriol, and verdegris moistened with water, will answer the purpose.

Copper and the alloys formed by its combination with zinc are gilded nearly in the same way as silver: but as their affinity for mercury is considerably less than that of silver, it would be difficult to make the amalgam of gold adhere to the burnished surface of these metals by the same means, and with the same evenness as takes place in the case just described. To obviate this inconvenience advantage is very ingeniously taken of the action of nitric acid to facilitate the adhesion of the copper and mercury in the following manner. The piece of copper, a button for example, is first cleaned by steeping in acid and subsequent washing, and is then burnished either in a lathe, or by any other means: after this it is dipped in a neutralized solution of nitrat of mercury, and in the space of a few seconds, owing to the strong affinity of nitric acid for copper the mercurial salt is decomposed, the copper takes the place of the mercury, and at the same time the mercury is deposited in the metallic state on the surface of the copper, covering it entirely, and strongly adhering to it. The gold amalgam is now applied, and the rest of the process goes on as already described. By this method of proceeding a given quantity of gold may be made to cover a larger surface than in any other way of gilding on metals: five grains of gold will compleatly gild both the upper and under surfaces of 144 copper buttons, each of them an inch in diameter.^b

There is no metal the gilding of which presents so many difficulties as iron, or rather steel. If the method of simple burnishing down is had recourse to, the heat requisite for this purpose will in many cases bring the temper of the steel too low: on such occasions the way already described of gilding copper is sometimes practised; that is, the parts of the steel to be gilded are pencilled over with nitrat of mercury, by which they are covered with a slightly adhering coating of mercury, then the amalgam is applied, and the gilding finished in the usual way. The objections to this mode of proceeding are first that a considerable heat is required, though inferior to that requisite for burnishing down, and secondly, that even with all possible care the gilding is apt to be rough and scale off. A very considerable improve-

ment on this method is to trace the figure of the gilding on the steel first of all with a brush charged with a strong solution of sulphated copper, in consequence of which a pretty thick plate of this metal is deposited on the steel to which it may be made to adhere with considerable firmness by means of the burnisher: thus the gilding is in fact performed upon the copper.

A new method of gold gilding upon steel has lately been published^c possessed of many advantages over the others, and which probably in time may attain a very high degree of perfection. It depends upon the well-known fact that if sulphuric ether and nitro-muriat of gold are mixed together the ether will by degrees separate from the acid nearly the whole of the gold, and retain it for some time in solution in nearly a metallic state. If ether thus charged with gold is spread by means of a pen or fine brush on the surface of highly polished steel the ether presently evaporates, leaving the gold behind in close contact with the steel, and the adhesion is considerably improved by the subsequent application of the burnisher. The dearth, and especially the rapid volatility of ether are objections of some moment, but may be got over by using the best oil of turpentine instead of the ether, which has nearly the same efficacy in decomposing the nitro-muriat of gold, and is both cheaper and not so very quickly evaporable.

Cold gilding upon silver is, we believe, at present entirely disused. It was performed in the following manner. A saturated solution of gold in nitro-muriatic acid was poured upon some linen rags, and when they were become dry they were heaped in a plate and touched with a hot coal. The fire gradually spread through the mass and reduced it to a heavy black ash. A soft cork being moistened in water was dipped in this ash, to which a part of it adhered, and was then rubbed on the surface of polished silver, upon which the minute particles of gold became fixed, and covered it with an extremely thin coating, which when burnished exhibited the genuine colour and lustre of this precious metal.

GLASS. *Verre*, Fr. *Glas*, Germ.

A glass in the common chemical use of the term is understood to be any substance or mixture, earthy, saline, or metallic, brought by igneous fusion to the state of a hard, brittle, uniform mass, breaking with a conchoidal fracture, passing into splintery, and with a high degree of lustre. Transparency is also a cha-

^b Phil. Mag. ix. p. 20.

^c Phil. Mag. xi. p. 144.

character of most glasses, for when opaque, it is generally owing to an excess of some matter, which, in a smaller quantity, would only give a tinge of more or less density.

Besides the general acceptation of the term glass, it is also applied more commonly to that most beautiful manufacture of siliceous earth, vitrified by various salts and metallic oxyds, which contributes so much to the purposes of science, to ornament, luxury, and to domestic comfort.

We shall first shortly give the results of a variety of experiments on *Vitrification* in general, and afterwards describe the manufacture of glass.

VITRIFICATION.

An immense repository of valuable facts on vitrification is to be found in the voluminous experiments of Mr. Achard, of Berlin,^a from which, together with the later experiments of Kirwan,^b Klaproth,^c Morveau,^d and other chemists, the following facts may be deduced. It may be premised that in all these experiments the mixtures were first reduced to fine powder, well mixed, put into a crucible, and exposed to nearly as strong a heat as the power of furnaces will give. Those of Achard were usually introduced into the porcelain furnaces of the royal porcelain manufactory of Berlin; of Klaproth, the same; of Kirwan and Morveau, in a wind furnace of very powerful draught, the intensity of which was in most cases marked by Wedgwood's pyrometer. The effects produced by the action of the materials on the crucible itself will be presently noticed.

§ 1. Of the Vitrification of Earths alone.

All the earths are of themselves infusible by any heat except that of a blast of oxygen gas, as ascertained by Lavoisier. Hence infusibility in culinary fire is properly given as a character of earthy bodies. But various mixtures of earths alone may be vitrified with more or less ease.

Of the binary combinations of earths none are vitrifiable except those in which one of the ingredients is lime or barytes (and probably strontian), and in equal proportion with the other, and at a very intense heat.

These earths therefore agree with the alkalies in their vitrifying power as well as in other alkaline properties, and like the alkalies this power is more active in dissolving flint than alumine or magnesia.

Silex and lime, in equal parts (according to Kirwan) melted at 150° of Wedgwood, into a

mass between porcelain and enamel, white, glazed at the surface, semitransparent at the edges, and feebly giving fire with steel.

Silex and barytes, in equal parts, (by Kirwan) gave at 148° Wedgwood, a hard mass not melted, but (by Morveau) melted into a green glass excessively hard and cellular. Two parts of barytes and one of flint gave (by Kirwan) a yellowish green porous enamel at 150°.

Silex with alumine, or with magnesia singly, and in any proportion, gave only a slightly cohering crumbly mass scarcely altered by the fire except in the parts touching the crucible.

Alumine and magnesia heated with the alkaline earths in any proportions gave only slightly agglutinated masses, but would not melt into a glass or even an enamel.

The alkaline earths mixed together fused more readily than any of the above mixtures, forming very perfect glasses, but which almost immediately begin to attack the sides of the crucible, and melt down with it in a strong fire into a vitreous slag.

With regard to combinations of three or more earths it would be endless to enumerate all the possible or actual experiments. Kirwan deduces from those which he made the following general results, which indeed might partly be expected from the known properties of the several earths: namely,

No compound of lime, magnesia, and alumine, in which the magnesia predominates will melt at a less heat than 160°: and to produce complete vitrification, the lime (which is properly the flux in this instance) must be equal to the two others. Where either the magnesia or alumine predominate the mass forms a porcelain, or imperfect glass.

In compounds of lime, magnesia, and flint, if the lime exceeds, perfect glasses will be formed, if the flint exceeds, few glasses will be formed, and never, if the magnesia exceeds.

In compounds of alumine, magnesia, and flint, the results are so far curious, that a porcelain, and even a perfect glass, may be produced in the proportions of 3 flint, 2 magnesia, and 1 alumine. The flint therefore here seems to act as a powerful flux, for when either of the two latter exceed, scarcely any approach to fusion can be obtained.

It follows, therefore, that the more fusible earths, of those here examined, when in mixture, are lime, and especially barytes, and next to them flint, and that alumine and magnesia are remarkably difficult of fusion in mixture,

^a Mem. Acad. Berlin, for 1779, 1780, 1781.

^b Mineralogy.

^c Essays, vol. 4.

^d Jour. Polytech. p. 3.

and according to their predominance give opaque white masses of a cellular, spongy, semi-fused texture; or in greater proportions, only porcelainous; or in greater, only loosely coherent and pulverulent.

§ 2. *Of the Vitrification of Earths by Metallic Oxyds.*

All the metallic oxyds that are not reduced by mere heat to the reguline state or volatilized, when urged by fire, run into a true glass which is always more or less tinged, and often possesses such a body of colour as to be quite opaque. The heat at which the oxyds vitrify varies extremely, in no instance is it less than a red heat, and in many a very intense white heat is required. All the vitrified oxyds are powerful fluxes for the earths, though less in proportion than the alkalies. They give their own colour to the vitrified mixture and much density.

The vitrifying power of several of the oxyds over the different earths has been examined in a series of valuable experiments by Achar, of which the following table will furnish an abstract. It may be premised that the flint was prepared from liquor of flints, and apparently very pure, the calcareous earth was carbonat of lime precipitated from the muriat by a carbonated alkali; the magnesia from Epsom salt in the same way, and the alumine from alum. The oxyd of copper was the green carbonated oxyd prepared from the nitrat by carbonat of potash; the oxyds of iron, lead, and zinc, the same; the oxyds of tin, bismuth, and antimony were also prepared by nitric acid, and therefore in the highest state of oxygenation.

All these mixtures were exposed in earthen crucibles to the heat of a porcelain furnace during the whole time required to bake the porcelain.

<i>Mixture.</i>		<i>Result.</i>	<i>Colour and Texture.</i>
Silex	1	scoria	black and polished—hard, giving sparks with steel.
Oxyd of iron.	1.		
Silex	2	not fused	black and friable.
Oxyd of iron	1.		
Silex	1.	scoria run through the crucible	black and hard—scintillant.
Oxyd of iron	2.		
Silex	1	not fused	
Oxyd of copper	1.		
Silex	1.	not fused	
Oxyd of copper	4.		
Silex	1	a solid mass but not fused	white and hard
Oxyd of lead	1.		
Silex	1.	fused, porous, and semi-vitrified	yellow—not scintillant.
Oxyd of lead	2		
Silex	1	perfect glass	green—not scintillant.
Oxyd of lead	3		
Silex	1	a coherent mass	grey—easily friable.
Oxyd of tin	1.		
Silex	1	vitrified	greenish yellow—not scintillant.
Oxyd of tin	2.		
Silex	1	remained in powder	
Oxyd of bismuth	1.		
Silex	1	perfect glass	deep yellow—not scintillant.
Oxyd of bismuth	4.		
Silex	1.	glass	colourless—scintillant.
Oxyd of antimony	1.		
Silex	2	not melted	grey and friable.
Oxyd of antimony	1.		
Silex	1.	remained in powder	
Oxyd of zinc	1.		
Silex	1.	melted only where touching the crucible	white—hard.
Oxyd of zinc	2.		

<i>Mixture.</i>		<i>Result.</i>	<i>Colour and Texture.</i>
Silex	1.	perfectly fused	grey—scintillant.
Oxyd of zinc	3.		
Lime (carbonated)	1.	a melted porous mass	black—scintillant.
Oxyd of iron	1.		
Lime	1.	melted, polished in the fracture, part of the copper reduced	red—scintillant.
Oxyd of copper	1.		
Lime	3.	melted, but porous	the same.
Oxyd of copper	1.		
Lime	4.	part only melted, the rest pulveru- lent	grey.
Oxyd of copper	1.		
Lime	1.	glass	greenish yellow—scintillant.
Oxyd of lead	1.		
Lime	2.	glass run through the crucible	yellow—scintillant.
Oxyd of lead	1.		
Lime	3.	remained in powder	
Oxyd of lead	1.		
Lime	1.	semi-vitrified	yellow—scintillant.
Oxyd of tin	1.		
Lime	2.	glass	greenish yellow—scintillant.
Oxyd of tin	1.		
Lime	3.	melted only where touching the crucible	grey.
Oxyd of tin	1.		
Lime	4.	glass	greenish yellow—scintillant.
Oxyd of tin	1.		
Lime	1.	vitriform mass	green.
Oxyd of bismuth	2.		
Lime	1.	glass penetrating the crucible	yellow—scintillant.
Oxyd of antimony	1.		
Lime	2.	remained in powder	
Oxyd of antimony	1.		
Lime	1.	glass penetrating the crucible	deep yellow—scintillant.
Oxyd of antimony	4.		
Lime	4.	a semi-transparent polished mass	grey yellow—scintillant.
Oxyd of antimony	1.		
Lime	1.	glass	deep yellow—scintillant.
Oxyd of zinc	1.		
Alumine	1.	only partially fused	
Oxyd of iron	1.		
Alumine	1.	a melted porous mass	black—scintillant.
Oxyd of iron	3.		
Alumine	1.	only partially fused	
Oxyd of copper	1.		
Alumine	1.	the same	
Oxyd of copper	4.		
Alumine	1.	remained in powder	
Oxyd of lead	1.		
Alumine	1.	the same	
Oxyd of lead	3.		
Alumine	1.	glass	deep yellow—scintillant.
Oxyd of lead	4.		

<i>Mixture.</i>		<i>Result.</i>	<i>Colour and Texture.</i>
Alumine	1	} a melted porous mass, not polished in the fracture	} grey—scintillant.
Oxyd of tin	2		
Alumine	1	} partially fused	}
Oxyd of bismuth	2.		
Alumine	1	} only partially fused	}
Oxyd of antimony	4.		
Alumine	1.	} remained in powder	}
Oxyd of Zinc	4.		
Magnesia	1	} half fused, but not cohering	}
Oxyd of iron	3.		
Magnesia	1	} a porous half-fused mass	} grey—scintillant.
Oxyd of copper	3		
Magnesia	1.	} not fused	}
Oxyd of lead	3		
Magnesia	1	} a porous melted mass, part of the oxyd reduced	}
Oxyd of lead	4.		
Magnesia	1	} beginning to fuse.	} grey—scintillant.
Oxyd of antimony	3.		

The above experiments (selected from a much larger number) are mostly confirmed by Kirwan. Notwithstanding various anomalies, owing principally to the action of the materials on the crucible itself, they are interesting in shewing in some degree the comparative fusibility of metallic oxyds, and in confirming the former observations on the fusibility of the respective earths. Among the metallic oxyds that of antimony seems to act the most powerfully as a flux, and next to this, lead. In almost all the above examples where fusion at all took place, the mass became hard enough to strike fire with steel, a degree of hardness which is not very common with the alkaline glasses.

§ 3. *Of the Vitrification of Earths with Saline Bodies.*

We shall here also give in a tabular form a few of the numerous experiments of Achard (A) and of Morveau (M) premising that in each the mixture of the earths and salts was contained in a clay crucible which was always acted on more or less during the vitrification, and where the salt was in excess was often entirely corroded, a circumstance which throws some confusion on the results. In the experiments of Achard the crucibles were exposed for three hours to the heat of a very strong wind furnace: in those of Morveau the crucibles were kept for two hours at a heat of from 22 to 26 Wedgwood, and therefore probably much lower than the former.

<i>Mixture.</i>		<i>Result.</i>
A. Silex	1	} a yellow glass, not hard enough to give sparks with steel.
Carbonat of potash	1.	
M. Silex	1	} a colourless transparent glass, but deliquescent from the excess of alkali.
Carbonat of soda (dry)	2.	
A. Silex	3	} a yellow glass, not scintillant.
Carbonat of potash	1.	
A. Silex	4	} a vitriform mass, yellow, hard, and scintillant.
Carbonat of potash	1.	
M. Silex	1	} a beautiful transparent glass, not at all soluble in water.
Borax (calcined)	2	
A. Silex	1	} a white porcellaneous mass, scarcely scintillant.
Boracic acid	1	

<i>Mixture.</i>				<i>Result.</i>
A.	Silex	1		} a hard transparent glass—scintillant.
	Boracic acid	2		
A.	Silex	4		} a white opaque melted porous mass—scintillant.
	Boracic acid	1.		
A.	Silex	3		} a transparent glass—hard and scintillant.
	Calcined borax	1.		
A.	Silex	4		} a mass resembling agate—but perfectly fused and scintillant.
	Calcined borax	1.		
A.	Silex	2		} a green scintillant glass.
	Sulphat of soda	1.		
A.	Silex	3		} a soft green transparent glass.
	Nitre	1.		
A.	Silex	1.		} scoria—the crucible entirely destroyed.
	Common salt	2.		
M.	Silex	1.		} a white opaque, puffy, vitreous mass, deliquescent and reddening litmus.
	Phosphat of soda and ammonia	2.		
M.	Lime	1		} a white spongy opaque mass, crumbling between the fingers.
	Carbonat of soda	2.		
A.	Chalk	2		} partly fused—the rest pulverulent—the crucible strongly corroded.
	Carbonat of potash	1.		
A.	Chalk	1		} a well-fused, polished, black scintillant glass.
	Carbonat of potash	2.		
A.	Chalk	4		} remained a white powder.
	Carbonat of potash	1.		
M.	Lime	1		} a fine transparent yellowish glass—the crucible strongly corroded.
	Borax	2		
A.	Chalk	4		} a well-fused, black, scintillant polished mass.
	Borax	1.		
A.	Chalk	3		} a yellow scintillant glass.
	Borax	1.		
A.	Chalk	1.		} a yellow glass—run through the crucible.
	Boracic acid	2.		
A.	Chalk	3.		} a hard yellow scintillant glass.
	Sulphat of soda	1.		
A.	Chalk	1		} a hard brown scoria—the crucible totally destroyed.
	Sulphat of soda	4.		
A.	Chalk	1.		} a hard yellow glass.
	Nitrat of soda	1		
A.	Chalk	1.		} a yellow scintillant glass—the crucible entirely destroyed
	Common salt	1.		
M.	Lime	1.		} a white opaque crumbly mass.
	Phosphat of soda and ammonia	2		
M.	Alumine	1		} a grey opaque ill-fused frit, not cohering to the crucible and deliquescent.
	Carbonat of soda	2.		
A.	Alumine	4		} remained unmelted and uncohering.
	Carbonat of soda and potash in all proportions from 1 to 12.			
A.	Alumine	1.		} partially melted, but soft and friable.
	Carbonat of potash	4.		

<i>Mixture.</i>		<i>Result.</i>
M. Alumine	1.	} a fine transparent clear green glass.
Borax	2.	
A. Alumine	1.	} remained pulverulent.
Borax	1.	
A. Alumine	1.	} part unfused and remaining pulverulent, the rest partially melted.
Boracic acid	4.	
M. Alumine	1.	} a green frit easily friable.
Phosphat of Soda and Ammonia	2.	

N. B. Most of the other combinations of alumine with the several neutral salts, even in large proportions of the latter, remained unfused, except where the crucible was entirely corroded and melted down along with its contents.

M. Magnesia	1.	} a white opaque incohering mass.
Carbonat of soda	2.	
M. Magnesia	1.	} a semi-transparent somewhat milky glass of a gelatinous appearance, but very hard and brilliant on the surface.
Borax	2.	
M. Magnesia	1.	} a white mass a little agglutinated but not adhering to the crucible.
Phosphat of Soda and Ammonia	2.	
M. Barytes (pure)	1.	} a very hard semi-vitrified mass, of a clear green.
Carbonat of soda	2.	
M. Barytes	1.	} a beautiful transparent glass with a faint yellow tinge, strongly adhering to the crucible
Borax	2.	
M. Barytes	1.	} a remarkably fine transparent glass.
Phosphat of Soda and Ammonia	2.	

§ 4. *Of the Action of Vitriifying Materials on the Crucibles that contain them.*

In estimating the proper action of vitrifiable substances on each other, the nature of the vessels that contain them should always be taken into account, as a want of this precaution may readily lead to the most erroneous conclusions. The celebrated Pott seems to have been the first who very distinctly pointed out this circumstance, and several curious experiments have been made by Gerhard,^c which deserve further notice.

This able chemist exposed a variety of natural minerals to a very high heat (that is fully equivalent to that at which cast iron melts) for an hour, under circumstances as exactly similar as possible, except with this difference, that one specimen of each mineral was inclosed in a crucible of clay, another in one of chalk, and a third in one of charcoal, and the difference in the result was particularly noticed. A few of these may also be given in a tabular form.

^c Mem. Acad. Berlin, for 1781.

<i>Substance used.</i>	<i>Result in the Clay crucible (A)</i>	<i>Result in the Chalk crucible (B)</i>	<i>Result in the Charcoal crucible (C.)</i>
Common flint . . .	{ opake and milk-white, but without fusion	{ opake and white, but with beginning fusion where in contact with the cru- cible	} as in A.
Marble . . .	{ run into a green glafs	{ no change	} no change.
Gypsum . . .	{ run into a radiated green glafs	{ no change	} no change.
Fluor spar . . .	{ melted and ran through the crucible	{ melted down with the crucible to a tough slag	} scarcely altered, ex- cept slight fusion at the edges.
Porcelain clay . .	{ compact, white and no signs of fusion	{ run into a hard blue clear glafs	} as in A.
Ditto, another kind	{ a compact mass partially melted	{ a perfectly black glafs	} as in A.
Reddle . . .	{ a black glafs covered with a crust of reduced iron	{ a semitransparent apple- green glafs	} a brown scoria con- taining grains of iron
Jasper . . .	{ no fusion, but the colour changed to brown	{ compleatly fused in the parts touching the cru- cible	} as in A.
Muscovy talc . .	{ a black glafs with inter- spersed grains of iron	{ the whole crucible was penetrated with a scoria so as not to fall to pow- der on exposure to air	} as in A.
Spanish chalk . .	{ only hardened	{ a grey semitransparent glafs	} as in A.
Basalt . . .	{ brown-yellow glafs with a crust of iron	{ a green scoria, also with a crust of iron	} a green glafs with many grains of iron.

In all the above experiments, except in that with the Muscovy talc, the chalk crucible was completely calcined to lime and fell into powder like common lime on exposure to air. The difference therefore between the action of the clay crucible and that of chalk, both respects the different fusibility of common clay and lime, and whatever action the carbonic acid that is escaping from the chalk may have upon the inclosed materials.

Similar and very valuable experiments have been repeated by Professor Klaproth in crucibles of clay and of charcoal, in which these differences are very striking.

Some of the most illustrative of them are the following.

White alabaster.

(*In the charcoal crucible.*) Was rendered moderately hard, its colour was white passing to straw yellow, with a fine grained earthy fracture, it adhered to the tongue and emitted an odour like a fulphuret: loss of weight .56.

(*In the clay crucible.*) Gave a black-brown glafs, very shining, little transparent on the edges.

Basalt.

(*In charcoal crucible.*) Fused into a compact brown glafs, transparent in splinters. Externally partly glazed brown, partly covered with a ferruginous crust, and large grains of iron.

(*In clay crucible.*) Gave a solid black glafs covered with a brown steel-grey veined iron crust.

Bohemian garnet.

(*In charcoal crucible.*) Gave a grey turbid glafs full of grains of iron.

(*In clay crucible.*) Melted into an opake almost compact scoria, whose colour internally changed by stripes from brown to green, very finely corroded.

Hornblende.

(*In charcoal crucible.*) A hardened ill-shaped mass with grains of iron. Colour light-grey, fracture uneven, without any trace of vitrification.

(*In clay crucible.*) Melted into a dense black-brown glass, transparent in the fragments; of a smooth surface and a flat conchoidal, glossy fracture.

Carrara marble.

(*In charcoal crucible.*) Was converted into quick-lime.

(*In clay crucible.*) Changed into a dense, clear, hard, pale, grass-green glass.

Strontianite.

(*In charcoal crucible.*) Form unaltered: hardened by ignition, rendered dull and very caustic: loss of weight 0.31.

(*In clay crucible.*) A clear bright grass-green glass.

Witherite.

(*In charcoal crucible.*) In repeated experiments the charcoal crucible was found for the most part consumed. Hence the witherite always entered into imperfect fusion with the contiguous part of the clay-crucible, which served as a case to the charcoal crucible.

(*In clay crucible.*) A green somewhat muddy, frothy glass.

In speaking therefore of the fusibility of all vitrifiable mixtures, the nature of the vessel that contains them should always be taken into account, so that as Klaproth has well observed, the usual division of earths and stones into fusible and infusible requires correction from this circumstance. Thus when strontianite, marble, and in general all species of calcareous earth vitrify in the melting vessels, it is entirely owing to the mutual action of the earth and the clay crucible, since they remain unfused in the charcoal crucible.

The charcoal also it will be observed in these experiments has often opportunity of acting in the usual manner of carbonaceous mixtures, as in reducing gypsum to a sulphuret of lime, and assisting in the calcination of the carbonates of lime, strontian, and barytes.

It also has another action which tends to diminish the natural fusibility of stones, and this is the reduction of the iron contained in them, which, when an oxyd, is itself a powerful flux. Hence it is that several stones naturally fusible will not vitrify in a charcoal crucible, of which the basalt is an example, as this mineral readily melts *per se* into a black glass; but when in contact with charcoal, the oxyd of iron is reduced, and globules of metallic iron sweat out as it were, or separate by a kind of eliquation, and the basalt then appears, if examined by a lens, almost wholly corroded but not changed

into a scoria or at all vitrified, except by a much more intense and long continued heat. This separation of the iron by charcoal, as Klaproth further remarks, takes place even in those stones which hardly appear to soften in the fire, and yet the globules of iron exude on the surface.

The colour of earths when perfectly vitrified and not in contact with charcoal, is for the most part of a cold sea-green passing into emerald green, and sometimes with a tinge of brown, where the glass is at all transparent. This is also observable in the common bottle glass, and those vitrescent mixtures where unpurified ashes are employed instead of pure alkali. This colour appears to be entirely owing to the presence of iron, which is always contained more or less in common clays and in vegetable ashes, as was discovered by Scheele, who obtained a satisfactory indication of this metal in the analysis of a green ordinary glass.

Some experiments of Mr. Musket^f on the affinities of the different earths for carbon at excessively high heats, shew in a satisfactory manner the gradual change produced on this natural green colour by the admixture of charcoal in various doses. A few of these we shall relate.

1. Some lime from calcined chalk was heated without addition in a crucible of Stourbridge clay, at a heat of 166° Wedgewood, and fused into a perfect dense glass, quite transparent and of a green approaching to emerald.

2. Fifty grains of the same lime were mixed with 1 grain of lamp black (a very pure carbon) and fused as before. The result was a lead-blue greenish colour. The charcoal had disappeared, but no globules of reduced iron could be observed.

3. Fifty grains of lime with 2½ of charcoal gave a dense glass, of a dark lead-blue. Part of the charcoal remained uncombined with the glass, and a number of globules of iron were revived.

1. A crystal of double refracting spar was melted *per se* as before into a very perfect glass of a rich green amber colour.

2. Twenty grains of the same spar mixed with one grain of charcoal fused into a deep fiery amber-coloured glass. All the charcoal had disappeared.

3. Twenty grains of the same spar with 1½ grain of charcoal melted into a glass of a cloudy milky lead-colour. A minute portion of the charcoal remained and many globules of iron were seen on the surface.

^f Phil. Mag. vol. 18.

From these experiments it appears that any admixture of carbon below what is necessary to reduce the iron only alters the shade of colour, giving in some instances an amber red, in others a dull lead-blue, which is possibly in part owing to an actual combination of the charcoal with the glass, but more probably to be chiefly ascribed to a partial disoxygenation of the oxyd of iron contained in the earth; as numerous experiments which will be afterwards noticed shew that the colouring power of all the metallic oxyds is materially affected by the degree of oxygenation. But when the charcoal is sufficient entirely to deoxygenate the iron the transparency of the glass is destroyed, and the colour is a muddy blue, like that of a partially reduced vitrified iron ore.

It is still doubtful whether carbon has any real affinity for any of the earths in a vitrified state, that is, whether the carbon is properly *dissolved* in the earthy glasses or only *diffused* through them in a state of very minute division. In all Mr. Musket's experiments with the other earths and carbon, where the latter was in any excess above what might be supposed necessary merely to deoxygenate the iron, the resulting glass received pretty uniformly a more or less deep tinge of muddy lead or slate-blue, which appears much more like a mere diffusion of the carbon through the glass than a perfect solution in it.

Some geological remarks on the subject of *Vitrification* will be noticed under that article, and we now proceed to the manufacture of Glasses.

GLASS invariably contains two essential ingredients, *silica*, and an alkali, either potash or soda, and these are all that are absolutely necessary for its composition, but other accessory substances are also used for particular purposes, among which may be particularly mentioned lime in the form of chalk, borax, oxyd of lead, oxyd of manganese, white oxyd of arsenic and nitre. Each of these requires some separate notice.

The *Silica* may be obtained from various sources, and of different degrees of purity, according to the fineness of the glass required. The siliceous material almost universally used in this country is sea sand, which is well known to consist of minute rounded grains of quartz, and is already sufficiently small to be used without any other preparation than that of washing. The finest sand is said to come from near Lynn on the coast of Norfolk, and also from the western extremity of the Isle of Wight. Another equally pure kind of *silica* is the common

black gun-flints, which before using must be heated red-hot and immediately quenched in cold water. The heat whitens them, and the water splits them in every direction, by which means they may afterwards be ground in mills without much difficulty. But this ground flint though largely used in the potteries in this kingdom, is scarcely ever employed in glass-making. The rounded lumps of white quartz found so abundantly in the beds of rivers in many mountainous districts, are sometimes used in foreign countries for this purpose, being first heated and ground to powder.

The *Alkali* used in this manufacture is either soda or potash, each being apparently equally well fitted for the purpose. It is always used at first in the state of carbonate, though the carbonic acid flies off in the process, for glass is a compound of *silica* and alkali, and not alkaline carbonate. These alkalies are used in every degree of purity according to the required quality of the glass. For the finest flint-glass the best pearlashes purified by solution and evaporation to dryness are employed, but the inferior glasses are made with the coarser alkalies, with barilla where this alkali is cheap, with common wood-ashes, and very largely with kelp. Though these alkalies are very impure, this does not prevent their dissolving the *silica* into a very good and perfect glass, for the impurities partly consist of neutral salts and partly of lime and other earths, all of which assist in the vitrification. Glass made from these alkalies has always more or less of a green tinge as in the common bottle-glass, owing to the presence of iron contained in these ashes. The methods of purifying and preparing these alkalies are described under the *Carbonates* of the respective alkalies.

Lime when employed in glass-making is generally used in the form of chalk. The property of lime and the other alkaline earths in promoting the vitrification of *silica* has been already mentioned, and shewn to be very powerful, though less so than that of the alkalies. Lime is used only in small proportions in the glass-pots, for the escape of the carbonic acid from the chalk during the fusion causes the materials to swell to an inconvenient degree; and also if the lime is in excess it acts very powerfully on the sides of the pots. Besides, an over proportion renders the glass opaque and milky on cooling though quite clear when hot. Experience has shewn that to 100 parts of *silica* with the requisite quantity of alkali, no more than about 6 or 7 of quick lime can be added

(or chalk in proportion) without endangering the clearness of the glass. The particular use of this ingredient, besides that of affording a very cheap flux, is to render the glass easier to work and less liable to crack by sudden changes of temperature.

Borax is perhaps the most powerful and valuable flux that is known. On account of its high price it is not used in any of the common glasses, but is employed in the finest kinds of plate glass and those articles that are required to be particularly clear and free from specks and bubbles. It is peculiarly well fitted for this purpose, as it renders all vitrescent compounds into which it enters remarkably thin-flowing, and therefore best adapted for being cast in a mould, which is the way in which these articles are manufactured. A very small quantity of borax will correct any deficient strength in the alkali.

The oxyds of lead, of which *litharge* and *minium* are the only ones employed in the large way, are of singular use in glass-making. Litharge melts *per se* into a very dense clear yellow transparent glass, remarkably soft and unctuous to the touch, fusible at a very low red heat, and when melted acting so powerfully on all earthen vessels as to run through the common porous crucibles in a very short time, almost like liquor through a sieve, but vitrifying and corroding the bottom of the crucible in its passage. Litharge is therefore a most powerful flux to all earthy mixtures, and it imparts to glass the valuable qualities of greater density and greater power of refracting the rays of light, and of bearing sudden changes from heat to cold without being so liable to crack, and also greater tenacity when red-hot, and therefore easier to be worked.

Most of the finer glasses contain a considerable quantity of this oxyd, particularly the London flint glass, or that sort which is used for most of the purposes of the table, for lustres and other ornamental works, which when cut into various forms display so beautiful a play of light, for artificial gems, and for most optical purposes. Glass containing much lead has, however, the great defect of being extremely soft so as to be readily scratched and injured by almost every hard body it rubs against. It is also extremely fusible, so that thin tubes of it will bend with ease in the flame of a candle, and will sink down into a shapeless mass at a very moderate red-heat. This quality for chemical purposes is sometimes an advantage, sometimes the contrary. When the lead is in

excess there is also some danger of the glass being corroded by very acrid liquors. Another defect also attending the use of lead is the extreme difficulty of uniting it so intimately with the flint and alkali that a whole piece of glass wrought with it shall be of equal density throughout, as the litharge on account of its much superior density is always liable to sink towards the bottom of the glass-pots before it can be detained by the other ingredients. This inequality subsists throughout, so that every stratum of the melted mass is of intermediate density between the stratum above and that below, which is apt to occasion *waves* in the glass when wrought, such as appear when water is gently poured on sulphuric acid, without mixing, and the vessel slightly agitated. This defect is particularly felt in some optical purposes where a certain thickness of glass is used.

The black oxyd of manganese was used in glass making long before its precise nature was understood. Its ancient name of *glass soap* denotes its particular use, namely, that of clearing the glass from any accidental foulness of colour which it would otherwise contract from the impurity of the alkali, or other materials employed, and especially the green tinge, owing as already mentioned, to the presence of iron.

Many curious circumstances attend the use of manganese in glasses, which have been beautifully illustrated by the researches of Scheele^a and Bergman.^b They are the following (accommodating the explanation given by these illustrious chemists to the antiphlogistic theory.)

When the oxyd of manganese is fused with any simple glass arising from any admixture of flint and alkali, or with borax and microcosmic salt, the result is a glass of more or less of a violet-purple colour, which when the manganese is at all in considerable quantity is so deep as to be almost entirely black. By this fusion the oxyd of manganese must in all probability lose most of its superfluous oxygen, or that which adheres so loosely as to be expelled by mere heat, and remains in that state (still very highly oxygenated) in which it is found after having been made to yield oxygen gas in the common way of procuring this gas. This indeed is proved by using this calcined oxyd of manganese which produces precisely the same colorific effect in the glass as the unprepared oxyd.

But if to this purple glass still in fusion in the crucible be added some charcoal, tartar, or any carbonaceous matter, or white arsenic, an effervescence takes place, the colour gradually

^a Essays.

^b Essays on the Analysis of Iron Ores.

becomes fainter, and at last entirely disappears, leaving the glass quite clear and transparent.

In the actual manufacture it is found that a very small dose of manganese produces no sensible tinge of purple (its natural vitrescent colour) where there is much of a green tinge to counteract, but if the quantity exceeds this point the purple immediately appears, and this in its turn is corrected by charcoal, or simply in the glass-house, by thrusting a billet of wood down into the melted glass, which immediately becomes charred by the intense heat, and causes the purple hue again to vanish with a slight effervescence of the glass and escape of numerous small air-bubbles.

On the other hand if a small quantity of nitre is added to glass containing manganese the purple colour is immediately restored, or, if present already, the discolouring effect of the charcoal is prevented till the nitre becomes alkalinized by the heat, and mixes with the other ingredients of the crucible.

These successive changes of colour are also shewn in a striking manner by means of the blow-pipe. Let a globule of microcosmic salt (compound phosphat of soda and ammonia) be fused with the blow-pipe upon a piece of charcoal, and add to it a small portion of the black oxyd of manganese, melt them together by the inner blue flame, and the globule will assume the violet purple peculiar to this oxyd. Let it be again fused and kept melted for a longer time and the colour will again disappear. Let the globule, now colourless, be only softened by the exterior flame of the blow-pipe, and the purple hue will return, but is, as before, again destroyed by a longer continuance of the fusion. The smallest particle of nitre laid upon the globule also immediately restores the red colour.

If the globule when colourless be now melted in a silver spoon, an iron plate or any metallic support, instead of resting on the charcoal, the red colour speedily returns, and will not be again removed by any continuance of the fusion so long as it remains on the metallic support.

The above appearances take place with borax instead of microcosmic salt, but with a little more tinge of yellow, and not quite the same readiness in assuming the different changes.

To explain these phenomena a supposed difference in the state of phlogistication has been resorted to by the former chemists, and of oxygenation by those of the present day. The oxyd of manganese gives the purple colour only so long as it remains in its higher state of oxy-

genation, but when in contact with charcoal, the latter of course partially deoxygenates it, carbonic acid gas is formed, the cause of the bubbles always observed on this occasion, and the colour is now lost. Nitre, on the other hand, is known to give out oxygen largely as soon as red-hot, and hence the manganese immediately retakes from this source the oxygen that the charcoal had robbed it of, and resumes its colouring power. So also when on the blow-pipe, the globule at first is coloured by the oxyd, but by keeping it entirely involved in the jet of flame, the charcoal on which it rests is consumed all around, and after a time the manganese loses oxygen, and with it its colouring power. But on again merely softening it with the outer flame (this latter containing probably little carbonaceous matter which is not actually burning in full activity) a nearly free access of air is allowed to the globule, the charcoal support is not rapidly consumed, and the colour is restored.

The great effect of the burning of the charcoal support is further corroborated by the impossibility of destroying the colour when fused upon any metallic body. Manganese therefore when in fusion appears to have a very weak affinity for just that portion of oxygen which makes the difference between the colourless and the red glass, readily parting with it to carbon of any kind, and also to other substances which will be immediately mentioned, but also again attracting it with ease from the air, from nitre, and other bodies when giving out oxygen.

The other substances which take away the colour from glass tinged red with manganese are all the salts with the basis of sulphuric acid, such as gypsum, sulphat of soda, &c. and also sulphur itself, likewise the oxyds of tin and iron and of some other metals. These substances however have only this power when also in contact with charcoal, as on the blow-pipe, but not in an earthen crucible, whence it may be presumed that they are themselves first deoxygenated and the sulphats brought first to the state of sulphurets, after which they may probably be in a state to absorb oxygen from the highly oxygenated manganese, and render it colourless. The metallic oxyds that deprive manganese of colour and oxygen are therefore probably *sub-oxyds*, and in the process become themselves more fully oxygenated. This agrees sufficiently well with the primary use of manganese in counteracting the green colour given to common glass by the iron of the salts used, for the

mon glass by the iron of the salts used, for the circumstance of its being green makes it probable that the iron is here in the state of sub-oxyd, and by absorbing oxygen from the manganese it prevents this latter when not in excess from mixing any of its own red-purple colour, and the iron itself, now more highly oxygenated, passes to the state in which it gives a yellow tinge, which being a lighter colour is much less perceptible, and much less injures the beauty of the glass. This change of iron from green to yellow by the action of oxyd of manganese also takes place in the liquid solution as observed by Scheele. On the other hand, manganese does not alter the yellow of glass tinged by the perfect oxyd of iron except in as far as it mixes its own purple with it.

It must be owned however, that it is difficult to account for the decolouring power which arsenic exercises over red glass tinged by manganese on the above supposition of the oxygenation of the arsenic at the expence of the manganese. For it is found that not only the white, and imperfect oxyd of arsenic has this effect, but all the arseniats, or combinations of the arsenic acid, which is already at the highest state of oxygenation, and this also occurs in close vessels; so that it is difficult to conceive how, when the arsenic acid is present, any oxygen should pass into it from the manganese, or how in any way the latter should lose oxygen whilst the glass loses its colour.

The perfect destruction of the tinging power of manganese by the addition of arsenic in any form is shewn as well in the simple glasses as in those in which any other colouring oxyd is present, for when the manganese is allowed to be active the colour is a compound of the manganese red, and the proper tinge belonging to the other substance. Thus a mixture of oxyd of cobalt and oxyd of manganese, in the colouring state is of a dark purple, but on the addition of any arseniat, or of white arsenic, the manganese is made inactive, and the proper cobalt blue alone appears.

Thus Klaproth^b made the following experiments on a natural mixed ore of cobalt and manganese. Half an ounce of flint, and as much calcined borax were combined with 10 grains of a mixed oxyd of cobalt and manganese, and vitrified in a porcelain pot. The result was a glass of a weak cloudy amethystine colour.

The same mixed oxyd was then dissolved in muriatic acid, and precipitated by arseniated

soda. This gave a lavender-blue powder which was a compound of arseniated oxyd of cobalt and manganese, and being combined with the same proportion of flint and borax now melted into a glass of a very fine sapphire-blue colour; the manganese therefore being made inactive, and the cobalt alone giving the tinge.

Hence the necessity where the red colour of manganese is wanted to avoid every thing arsenical, and also nitre is generally added to keep the manganese always at the proper state for imparting its colour.

The oxyd of manganese is a very powerful flux for all earthy matters. This is seen in the result of all the attempts to reduce it to a reguline state in the usual way of combining with a saline carbonaceous flux, and heating in a naked crucible. Not a particle of the oxyd is reduced in this way, but the crucible constantly runs down, in a heat sufficiently intense for the reduction of manganese, together with all its contents, into a green slag. The only way hitherto known of reducing this oxyd is to enclose it without any saline or earthy addition in a crucible lined with charcoal, and apply a very intense heat. Manganese as well as lead gives a great density to glass, and also like lead it always settles somewhat to the bottom of the pots where it accumulates, and being here out of the way of most of the decolouring additions it gives a purple to the glass immediately adhering to the bottom, and partly corrodes the pots, so that when these are worn out and broken up, they are deeply encrusted with a thick purple vitrescent slag easily separable by the hammer.

The white Oxyd of Arsenic is another flux used pretty largely in glass-making. This substance (as fully mentioned under the article *arsenic*) is volatile in the fire in proportion as it approaches the metallic state, and hence it is of advantage to employ nitre to oxygenate it more highly, and make it more fixed. Its use in correcting the purple red colour of manganese has been just mentioned. Arsenic is a very powerful flux, and very cheap, but must be used only in great moderation, for it takes a longer time to mix intimately with glass, and to allow it to be perfectly clear, than any other of the additions commonly employed. Glasses in which the arsenic is not thoroughly or long enough fused have a milky hue, which encreases by age: when the arsenic is in excess they tend to deliquescence, gradually become soft, and are decomposed. They are besides unsafe as

^b Essays, p. 577.

drinking vessels. The arsenic is constantly volatilizing from the arsenical glass when preparing, that is, till it is intimately united with the rest of the glass, after which however it cannot again be separated by heat or any common means.

As arsenic is entirely volatilized when in contact with any carbonaceous matter another use has been made of it, which is to disperse any such matter which may remain in the glass, owing to a defect in the calcination of the alkali, or any other cause.^c When this happens, small lumps of white arsenic are sometimes thrust down to the bottom of the glass-pots and stirred in with the contents, and the arsenic meeting with the unburnt carbon diffused through the glass unites with it, is speedily volatilized with it, and the glass is left freed both from the adhering carbon, and also from most of the arsenic that was added. The motion excited through the melting glass by the volatilization of the arsenic is also thought useful in hastening the complete vitrification of the ingredients.

Nitre is used in glass-making only in small quantities, and is an accessory ingredient to fulfil particular purposes. This salt at a heat even much below that of the glass-pots is readily decomposed, giving out much oxygen, nitrous gas and azot, and leaving behind its pure potash. It is of service in destroying any carbonaceous matter in the ingredients of the glass (with which it should be mixed before fusion) and its use in fixing arsenic, and in keeping up the tinging power of manganese has been already mentioned. The same circumstance of keeping metallic oxyds up to their highest state of oxygenation, also renders this salt often useful, and even necessary in the preparation of some others of the coloured glasses.

Of the proportion of Silica to the Saline fluxes.

The exact proportion and number of ingredients that enter into every species of glass cannot easily be obtained with any certainty, though many apparently good mixtures are given by different authors which will be afterwards mentioned. But some observations may be made on the solvent power of mere alkali over siliceous earth, which is the basis of the rules for the composition of glass, as, strictly speaking, nothing else is necessary for the formation of glass than a solution of silica in alkali by a melting heat, and all the other additions are more properly useful than necessary ingredients.

When silica is melted with twice its weight, or more, of dry carbonated alkali, either potash or soda, the result is a very soft deliquescent vitreous mass, always more or less opaque, strongly alkaline to the taste, and which on exposure to moist air, or more speedily if put into water, totally dissolves into a clear liquor which is a solution of silica in alkali. This silicated alkaline solution is decomposed by all the acids, which separate the silica in the form of a white powder.

When the alkali employed (meaning all along in this place the dry carbonated alkali) only equals the silica in weight, or at least does not much exceed it, the glass is now transparent, but is still soluble in water as before.

It is not till the alkali is diminished to about one half of the weight of the silica that the glass becomes perfectly hard and insoluble in any corrosive liquors, (the fluoric acid excepted) and in short, acquires the character of a perfect glass.

This proportion therefore, that is, two parts of sand to one of alkali is usually the datum on which the doses of the species of alkalies actually used are regulated.^d Thus if common wood ashes (of which the alkaline part is reckoned at no more than 10 per cent.) are employed, 100 lbs. of these would require no more than about 20 lb. of sand. If the best Spanish barilla containing from 45 to 50 per cent. of carbonate of soda, be used, an equal weight of sand may be added; but if purified pearl ash be taken, it will melt down perfectly twice its own weight of sand.

But glasses composed merely of pure alkali and sand require a very strong fire for their fusion, and are hard, harsh, and difficult to work. They are therefore never used alone, for even when common ashes and sand are the only ingredients, the ashes contain an abundance of earth and other substances. As one half the weight of the sand is reckoned an abundant allowance of alkali, it follows of course that when litharge, arsenic, borax, or any other fluxes are employed, the quantity of alkali will be proportionally diminished.

It must not be supposed that the glasses themselves contain nearly the original proportion of silica and alkali that was put into the glass-pots. Of these two materials the alkali is abundantly volatile in the intense fire necessary for glass-making, but the silica is absolutely fixed, and hence in proportion to the strength and continuance of the fire the relative

^c Løysel, Art. de la Verrerie.

^d Encyclop. Arts & Metiers. Article Verre.

quantities of the two are constantly altering, that of the alkali diminishing, and that of the filex and other ingredients increasing. That the alkali does really volatilize, and very rapidly at first when in large proportion in the mixture, is put beyond a doubt by the dense vapour which always proceeds from the glass-pots when the glass is first heating, and which corrodes the covers of the crucibles, and by various other tests is proved to be part of the alkali escaping. This may partly be owing to a want of thorough mixture of the filex, which, though in grains when sand is used, is very far short of intimate mechanical mixture. No continuance of heat indeed can drive off all the alkali, for when once melted into glass, it must remain as such, but the solvent power of alkali upon filex increases in proportion as the temperature is raised, as occurs in most other cases of solution.

Mr. Loyfel^e has the following remarks on the subject of the volatilization of the alkali, but it is to be wished that he had given more of the particulars of the experiments on which they are founded. If a mixture of two parts of sand and one of alkali be exposed for the accustomed number of hours in the ordinary glass-house fires (about 8000° degrees Reaumur) the glass when finished will contain no more than a fourth part of alkali, all the rest having been dissipated. If the glass be heated so as to retain no more than about 15 or 20 of alkali to 100 of filex, it will be very hard, transparent, and almost equal in beauty to rock crystal. Of a glass originally made of two parts of sand and three of alkali, Mr. Loyfel observes that if kept in the heat of 3000° for one or two days the result will be a soft glass retaining nearly equal parts of alkali and filex; if further heated to 9000° a solid glass will remain composed of about four parts of filex to one of alkali; and lastly, if urged to a heat of 10 to 12000° the glass will be extremely hard, brilliant, and will consist of no more than three parts of alkali to seven of filex.

All the common alkalies are largely mixed with various neutral salts, particularly common salt, and some of the sulphats. It does not seem entirely ascertained what share these have in the vitrification. It is generally asserted that they are merely inefficient and act as extraneous bodies, and it is certain that during the fusion of the glass materials a quantity of scum rises to the top of the pots, which is a very heterogeneous mixture of common salt and other

neutral salts and other impurities of the alkali, as will be presently noticed. Common salt being readily volatile in a full red heat can scarcely be supposed to contract much permanent union with the filex, and yet if a quantity of this salt be inclosed in a well luted crucible and heated without addition, it will readily penetrate the sides of the vessel, and deeply corrode them in its passage.

But the sulphats being fixed in the fire can withstand without volatilization all the heat of the glass-pots, and at this temperature they are decomposed largely by the filex, this earth uniting with the alkali of the sulphat and the acid flying off alone. Thus if three parts of sulphat of soda and one of filex are put into an earthen retort with a receiver, and the fire strongly urged to whiteness, a transparent glass of filex and soda will remain, and the receiver will contain much sulphureous acid.

This is one of the very frequent examples of chemical affinity being changed by temperature, for at any common heat the sulphuric acid has a much stronger affinity for alkali than this has for filex, and therefore will decompose the solution of filicited alkali, and separate the filex. Of the common neutral salts therefore, the muriats probably add but little to the quantity of real flux, but on the contrary, the sulphats are important additions, and leave in the glass pot the alkali or earth with which they were united. Hence in some places sulphat of soda where impure and not reserved for other purposes, is sold to the glass-makers, and found to answer compleatly. This is the case at Freyberg, where the pyritical ores of silver and copper after roasting are converted into sulphats, from which a large quantity of impure sulphat of soda mixed with some arseniats is obtained, which is used without preparation as the sole flux in glass-making.^f

Of the Glass Furnaces and Pots.

Glass is made in large deep pots or crucibles closed every where except at one side-opening, and arranged round a kiln or dome-shaped oven, into the middle of which they project, and by which they are entirely enclosed except at the side orifice above mentioned, which opens into a small recess formed by the alternate projections of the masonry and flues of the kiln in which recess the workmen stand.

The kiln is supported on arches, beneath which is a large space for a brisk and copious draught of cold air from without. The floor of the kiln nearly level with the ground is

^e Art. de la Verrerie.

^f Journ. de Phys. tom. 51.

covered with a grate of very strong iron bars on which the fuel is thrown, and the flame draws very strong and fierce round the pots, and passes out together with the smoke, in one body through the top of the dome which is lengthened into a chimney for the space of a few feet. The precise construction of the glass-house can only be understood by figures, which cannot be given in this place. At the top of the dome between the pots and the chimney, is a kind of broad covered shelf which is heated by the flame in its passage round it, but to a much less degree of intensity than the pots, and serves as a receptacle for the glass as soon as wrought, in which it may cool slowly and gradually. This is the *annealing oven*.

Very great care is required in building a glass-house to form the bricks of an earth which combines in the highest degree the qualities of density and infusibility, so as to enable them to withstand the unceasing action of very strong heat for a great length of time, for the fires are seldom suffered to go out from the time the furnace begins to be in action, till the inevitable wear and fusion of the walls renders a repair necessary, which may be in about two or three years. But still greater attention is required in selecting proper materials for the glass-pots, as these have to withstand for a given time not only the constant action of a very fierce fire, but also the solvent power of the glass itself with the variety of powerful fluxes in full vitrification. The pots therefore, being made of earth, must necessarily be themselves always gradually dissolving in their contents, and hence, besides the property of difficult fusibility, an earth of considerable purity is required for these, so that a small admixture with the glass may not injure its quality.

The chief material both of the walls of the furnace and of the pots is clay, as it is of almost every vessel and substance destined to bear a long and violent heat. This is mixed with sand, in different proportions according to its quality, for the fire-bricks and other parts of the furnace. On an average a fine stiff clay will require about two-thirds as much of sand to bring it to such a consistence that it will work easily, dry into a very compact mass, and resist the impression of fire for a length of time. Still however, this addition of sand renders it in some degree fusible, so that when the fire is in activity, drops of vitrified earth are constantly and slowly falling from the walls, some of which cannot be prevented from dropping into the glass and mixing with it. The crucibles

are made of a still more refractory mixture, which consists simply of raw and of burnt clay, the latter is called technically *cement*, and is procured from the remains of the former furnaces when pulled down for reparation. As clay loses its plasticity by baking, it then answers all the purposes of sand in diminishing the tenacity of the mass, and especially in lessening the shrinkage whilst drying, and being the same kind of earth as the unbaked, it adds nothing to the vitrescibility of the material, for as has been already shewn, earthy compounds are, *ceteris paribus*, fusible in proportion to the number of ingredients of which they are composed.

The particular manipulations employed in constructing a glass-furnace and pots are foreign to the present purpose: very great precaution is used in drying them thoroughly and very gradually. This is peculiarly necessary in making the pots, for as they are intended to hold a considerable weight of glass, and to last many months, they must be made very thick and strong, and therefore would readily crack without much care. When finished they are first kept in a warm sheltered room for many weeks to dissipate much of their moisture, and the small fissures formed by the unequal shrinking of the clay are closed up by beating gently with a mallet. They are afterwards heated extremely gradually in a small oven made for this purpose, and are slowly brought to a red heat and kept there the requisite time, after which they are removed, whilst still hot, to the furnace and soldered down to their place by fire clay. A still further shrinkage takes place when in the furnace, for which reason they are let to stand empty for a day or two before they are fitted to receive the materials for glass. These pots last on an average about a year, and hence they must be changed once or twice during the continuance of the furnace itself.

The fuel used in this country is constantly coal, and the best is of the kind that gives a strong steady blaze. As the glass-pots open only outward none of the fuel or flame comes in contact with their contents, except through any accidental crack in the clay soldering.

Considerable variety prevails respecting the exact form and construction of the furnace and crucibles, in different countries, and also according to the kind of manufacture, and in particular the plate-glass furnace requires a different arrangement.

Of the Fusion and working of Glass.

The sand, alkali, and other materials for the

glafs after mixture are usually first calcined for a longer or shorter time by a separate operation before they are transferred to the glafs-pots. This operation is called *fritting*, and is performed either in small furnaces close adjoining to the proper glafs furnace and heated by the same fuel after the chief force has been spent upon the glafs-pots, or else in small furnaces or ovens constructed for the express purpose. The uses of fritting are, to drive off all moisture from the materials which might endanger the glafs-pots, to expell part of the carbonic acid from the alkalies and chalk, and thus to moderate the swelling up in the glafs-pots, and especially to cause an adhesion or commencement of chemical union between the alkali and silice, and the metallic oxyds. For if the raw materials were immediately exposed to the intense heat of the glafs-pots, the alkali would flow thin like water, and the grosser particles of the sand and the heavier oxyds would fall to the bottom, leaving the alkali above nearly disengaged, and therefore liable strongly to act on the crucibles, and also a large portion would be rapidly volatilized to mere waste. The glafs materials therefore would thus have an excess of sand from the loss of the alkali, and a portion would remain at the bottom unvitified.

Fritting should be gradual, and carried to the point of semi-vitrification, in which the materials strongly adhere and begin to become pasty, but are still opaque and not yet homogeneous. It has the further use of destroying any carbonaceous matter.

When the materials are sufficiently fritted they are thrown into the glafs-pots with clean iron shovels through the side opening. The fire is previously raised to its greatest intensity to prevent the whole furnace from being chilled and to save time. As the fritted materials are much more bulky than when they fall into a thin-flowing glafs, the pots receive their full charge by two or three successive portions, the last-added being always thoroughly melted down before a fresh charge is thrown in. When full, the side opening is closed up with wet clay, except a small hole for examining the work, which closure is pulled down when the glafs is well refined and about to be worked off.

As soon as the frit begins to feel the action of the fire in the glafs-pots which is immediately raised to its greatest pitch, it sinks down into a soft pasty state, which gradually encreases in tenacity till a perfect fusion is

effected. It is still however opaque at first, owing to the rising of a quantity of a white porous scum, the nature of which has engaged much attention, and is known by the name of *san-diver*, or *glafs-gall*. This substance appears to be a confused mass, consisting of all those salts contained in common alkalies which readily melt at somewhat less than a glafs-making heat, and are either naturally considerably volatile, or have little if any affinity for silice, and do not unite in the composition of glafs, but being superficially lighter, rise to the top. There is another heterogeneous substance also called *san-diver*, which sometimes is found at the bottom of the pots, and is taken out when the whole is worked off. The nature of this is very different from the other, and consists apparently of a vitrified mass of arsenic and earthy impurities. But the scum or proper *glafs-gall* is almost entirely saline. When laded out and cooled it forms a white crumbly mass, sometimes quite white, and at other times brown and fouled, and strongly saline, but not very uniform in its composition, being sometimes merely salt, often very bitter, probably as common salt or sulphat of potash predominate. Glafs-gall is very volatile in a strong fire, so that it is constantly dispersing from off the surface of the glafs in a dense vapour, at first thick and black, afterwards whiter, which very powerfully corrodes the top of the crucible in its passage. If the fusion were continued long enough the whole would be dispersed merely in this way, but it is generally scummed off with iron ladles, and sold to metal-refiners as a powerful flux. As part of the alkali itself certainly is dissipated by the continuance of fire, partly before it can unite with the silice, partly from the glafs itself, much of the corrosion of the pots must be owing to this circumstance, and probably it must also unite in part with the glafs-gall, which renders it slightly deliquescent. An abundance of this glafs-gall is one of the greatest inconveniences that the glafs-maker can meet with, for it requires a considerable time of very strong heat before the whole can be dissipated, or if the glafs be wrought before it is thoroughly purged of this material it is full of bubbles, unsound, and has a cloudy gelatinous appearance. Glafs made with potash is more likely to suffer from glafs-gall than the soda glasses, for the potash-glasses are harder and do not run so thin as the others, and the glafs-gall arising from them does not so easily dissipate in the fire.

During this part of the process small samples

are occasionally drawn out of the pots with an iron rod to examine the state of the materials, and gradually the glass becomes more and more flexible, dense, and less brittle, and at last the glass-gall is entirely dissipated, and the vapours which it occasioned are no longer to be perceived. This is the first and very well defined step in the process of glass-melting.

The glass is now full of minute specks or bubbles which the continuance of the heat causes to expand and burst at the top, till at last it refines beautifully clear, transparent, and colourless, as is seen by the samples which are from time to time taken out and cooled. This second process, namely, from the cessation of the vapour of the glass-gall and its thorough removal, to the time when the glass is perfectly clear and free from bubbles, is called the *refining*. The glass is now complete, but is of too thin a consistence to be wrought, it is therefore cooled by stopping the draught of the fire round the individual pot, and in cooling it thickens to the working point. The clay with which the opening was luted is then picked off and the working begun. But if the glass is to be cast into plates (as all the large mirrors are) a much shorter cooling is required, as for this purpose it is required to flow very thin and hot.

The particular manner of managing the pots, and the alternations of filling and working them off varies considerably, and depends chiefly on the convenience of the manufacturer. Sometimes half the number of pots (which are generally six in common glass-houses) are kept in the working state, whilst the materials are melting or refining in the three others, and sometimes they are all filled together. On an average it takes about forty-eight hours for the fine flint glasses, from the time that the pots are first filled till the glass is ready for working, but there is no occasion to use it immediately, as it may be allowed to remain a considerable time at a low working heat without any injury.

When the glass is cooled down to the working heat, which is a very full red, it has a kind of consistence and tenacity not exactly to be found in any other substance in nature. It is just soft enough to yield with the greatest ease to any outer impression, even to the force of the breath when urged pretty strongly in the center of the glowing mass, and may be bent, pulled out and shaped in every possible way; and its tenacity is such that it extends uniformly with-

out producing any cracks or fissures, but when stretched to the utmost it pulls out to a solid string, the diameter of which is constantly decreasing till it separates from the mass in a thin capillary thread. As it cools it stiffens, and becomes perfectly brittle, which takes place when no longer red hot, and at this time also it becomes transparent. Melted glass adheres very feebly to polished metal, so that it is wrought with bright iron tools with the utmost ease.

Almost every kind of glass vessel, and utensil, common window glass, and in short, almost every manufactured glass article except plate-glass, is shaped out of a hollow globe formed by blowing. The instrument used for this purpose is simply a hollow iron rod about four or five feet long, which the workman first dips in the glass-pot and turns about till a sufficient mass of the melted glass adheres to it, he then holds it near the ground by which the mass pulls out and lengthens by its own weight, and then blows strongly through the tube. The breath thus penetrates the center of the red-hot mass, and immediately extends it into an uniform hollow globe of the required thickness. This must be immediately blown out as large as intended, and the force of the breath kept upon it for a few seconds till it stiffens by cooling, otherwise it would again sink in by the compression of the denser external air. This operation produces a hollow globe, adhering by a neck to the iron rod, and is the original form out of which the others are fashioned.

It would be impossible to give in a short space an adequate idea of the ease and simple dexterity by which, with a few instruments, this most beautiful substance is stretched out, enlarged, closed, perforated, and formed by a few ingenious manœuvres into all the common utensils. As a single and short example, the making of a common tumbler may be given. A hollow globe with a short neck being first blown on the iron rod as above mentioned, it is taken off in the following way: an assistant dips the end of a short solid iron rod into the glass-pot, and brings it out with a little of the melted glass adhering, this is immediately thrust against the bottom of the globe at the part directly opposite the neck, to which it firmly unites, so that the globe becomes cemented upon this second rod by means of the melted glass. The workman then wets a small piece of iron with his mouth and lays it on the neck of the globe which is still extremely hot, and this cracks it quite round in a second or two, so that

with a slight pull it comes off and detaches the hollow rod, leaving the globe now open at the neck, and transferred to the second rod at the opposite side. The globe being now open is again softened by holding it a few seconds over the mouth of the glass-pot, and is cut away from the open end to the form of a cup by iron shears. The workman when fashioning the globe usually sits upon a kind of arm chair, the arms of which slope forwards, and are covered with a flat smooth iron plate, and by laying the iron rod straight before him, resting on both the arms of his seat, and twirling it backwards and forwards, the hot glass at the end is made to revolve like clay on a potter's lathe, and thus is opened, widened, or compressed at pleasure by any simple iron instrument that is pressed against it. The globular cup is thus extended easily into a cylinder, or made barrel-shaped, if this be the required form, and is smoothed up at the edges. It only now requires to be separated from the iron rod, which is done as before, simply by wetting it at the point of attachment, and the tumbler drops off complete. This last operation leaves that burr or roughness with sharp fragments which is seen at the bottom of all glass vessels unless taken off by grinding.

Another important process is required before the glass vessel is fit for use, which is that of *annealing* or cooling very gradually. All glass articles require annealing except those that are very thin and uniform without joining or burr of any kind. Without this precaution the glass remains always liable to fly by the least change of heat and cold, by the smallest scratch, or even apparently without any external cause. The precise mechanical cause of this disposition to crack in unannealed glass is very difficult to explain, but generally speaking it is supposed to be the forcible contraction of the outer part by sudden cooling, whilst the inner portion is still soft and half-fluid, so that the whole fixes with a permanent strain or inequality of pressure of one part upon the other; and as glass is extremely elastic, though brittle, any force which tears asunder a portion, however small, of the tense part, communicates a strong and sudden impulse over the whole mass. The annealing is generally performed in a hot chamber built for the purpose at the top of the glass-house above the crucibles and a little below the chimney as already mentioned. The heat is here so moderate as not to soften the glass, and the articles are gradually withdrawn to a cooler part till they are cold enough to be

taken out for use. Common articles are generally annealed in the course of a day. The place of all others in which ill-annealed glass is most liable to break is at any point of junction where two pieces are cemented together when hot, and as different kinds of glass contract to a different extent, two dissimilar pieces of glass should not be joined together.

The hard glasses, and those in particular made only with alkali and earths require much more annealing than the softer and more fusible glasses into which litharge enters largely.

The extraordinary fragility of unannealed glass is shewn in a very striking manner by two kinds of experimental toys made for the purpose, the one is the *Bologna phial*, as it is usually called, and the other the *Rupert's drop*. The Bologna phial is simply a phial of any form whatever, made of any kind of glass, but much thicker at bottom than at top, and cooled immediately without annealing. These being pretty stout from their thickness will bear a smart blow with a wooden mallet or any blunt instrument, or the concussion of a leaden bullet dropped into it from a considerable height, without injury; but if any sharp body however small, such as a large grain of sand, or better a shiver of a gun-flint be dropped in from only a few inches height, the bottom cracks all round just above the thickest part and drops off. The same effect happens if the bottom be slightly scratched with any hard body. When very brittle, if a hard angular substance such as a cut diamond be dropped in, it sometimes will pass through the bottom, though very thick, with apparently as little resistance as through a spider's web. These glasses when they have received the first injury do not always crack immediately, but remain whole sometimes a few minutes, sometimes for hours, and then suddenly give way.

The Rupert's drop is simply a small solid lump of green bottle glass poured when red-hot into water, and therefore is a rounded lump gradually extended into a kind of tail nearly capillary at the extremity. This solid lump will bear very considerable violence on the rounded end without injury, and is altogether extremely tough, but when the least portion of the thin end is broken off, the whole bursts with a smart snap, instantly crumbles into a countless number of fragments as small as fine sand, which from their very minuteness do no other injury to the hand holding it, than a slight stinging from the sudden concussion.

This most singular phenomenon is obviously

owing to some permanent and very strong inequality of pressure, for when they are heated so red as to be soft and merely let to cool of themselves, this property of bursting is entirely lost, and at the same time the specific gravity of the drop is encreased.^s

The peculiar brittleness of the Bologna phial is also removed by again heating and cooling slowly.

A defect in the annealing of common window glass is also shewn when cut by the diamond. When the glass is well annealed the diamond cuts it with moderate ease, making an uniform smooth furrow, at first dark, but which gradually opens and then appears as a bright silver thread; but when the glass is badly annealed, the diamond works with much more difficulty, the cut opens very slowly, and often flies into a different direction, or the glass entirely breaks.

The other more common defects of glass are a liability to be acted on by corrosive liquors (which takes place when too much saline flux has been used) and also a number of visible imperfections, some of which materially injure the soundness as well as beauty of the manufactured articles. The chief of these visible defects are *striae*^h, *threads*, *tears*, and *knots*. The *Striae* are undulating waves in the glass, perfectly transparent and vitrified, but which produce much strange distortion when used for windows or for optical purposes. This defect arises from the imperfect mixture of the materials, and the great difference in their specific gravities. For the gravity of glass made simply with alkali and sand is about 2.3 or 2.4, that of alkali and crucible clay, about 2.5; that of alkali and chalk 2.7 or 2.8; whilst the vitrified oxyd of manganese alone weighs 3.2 and the glass of lead 7.2 nearly. Therefore when these are all together melted in the glass-pot, if they are not thoroughly mixed, they are in the case of liquors of unequal density in contact with each other and slightly agitated so as to shake the different materials into streaks or waves.

The defect from this cause is seen very strikingly in ordinary prisms, or pieces of solid glass of a certain thickness, which are seldom quite uniform in density throughout. For very nice purposes it is often of use when small moveable crucibles are used, to invert them when the glass is melted and empty the contents, whereby the heavier parts become mixed with the lighter as they fall through them.

Threads in glass-making are those streaky

^s Own Exper.

filaments which arise from the vitrification of the clay. They are generally green and often render the glass more liable to crack at these parts.

Another and one of the worst defects is *Tears*, or drops of vitrified clay falling down from the furnace into the pots and entangled with the glass. Articles made of glass with this defect are always very brittle, and generally break of themselves by slight changes of heat and cold. This is the more likely to happen in proportion as the tear is nearer the surface.

Glass when not sufficiently refined by continuance of the melting heat is always full of small bubbles. This fault may also happen from a deficiency of flux which renders the glass less fusible, and therefore stiffer during the ordinary time and degree of heating so that the bubbles cannot easily disengage themselves. Hence the soft fusible glasses with much lead are much less liable to this fault than the hard green bottle glass which is made only of alkali and earth.

Another defect is *knots* which arise either from a portion of sand that has escaped vitrification and remains entangled in the glass, or from a remaining quantity of glass-gall; or from bits of the crucible which may be accidentally knocked off by the iron instruments used in the working.

Of the different kinds of Glass.

Though an infinite variety is found in the quality and composition of different glasses, there are some principal kinds made for totally distinct purposes which may be shortly noticed.

The *flint glass* of London and other parts of England (called by foreigners *crystal*) is that beautiful, soft, brilliant, fine glass of which both the common and finest articles of white glass in domestic or ornamental use are manufactured. Many optical instruments are also made of the same material. It is particularly distinguished for the quantity of litharge which enters into its composition, on which account it is by far the heaviest, the most brilliant, the softest, and the easiest to work, and also the most expensive.

The precise proportions of ingredients are not usually known, but the following is said to make an article of the best quality, namely; 120 parts of fine clean white sand, 40 of pearl-ash well purified, 35 of litharge or else minium, 13 of nitre, and a small quantity of black oxyd of manganese. The distinct use of these in-

^h Løysel.

redients has been already explained. Very different proportions will also produce a fine glass of similar quality, and in particular the quantity of lead may be much increased which naturally gives a yellow tinge but which the manganese counteracts. The following composition for a fine crystal glass is given by Løysel: 100 pounds of white sand, 80 to 85 of red oxyd of lead, 35 to 40 of pearlash, 2 to 3 of nitre; and one ounce of manganese. The specific gravity of this glass and of the common London flint glass is about 3.2.

The oxyd of lead is so abundant in this glass that it may be partially reduced in a very curious manner. If a tube of it be made red-hot and hydrogen gas passed through, the whole inner surface becomes covered with a half-brilliant black coating owing to the reduced lead, and moisture appears at the further end. This was discovered by Dr. Priestley.

Crown-glass is the name given to the best sort of window glass, the composition of which varies considerably, but it differs essentially from the last in containing no lead nor any metallic oxyd except manganese and sometimes oxyd of cobalt in minute doses, for the sole purpose of correcting the natural colour and not as a flux. This kind of glass therefore is much harder and harsher to the touch than the flint glass, but when well made is a very beautiful and perfect article. The composition is sand, alkali, either potash or soda, the vegetable ashes that contain the alkali, and generally a small portion of lime. A small dose of arsenic is often added to facilitate the fusion. Zaffre or the oxyd of cobalt with ground flint is often used to correct the dingy yellow which the inferior kind of crown-glass naturally acquires, and by adding the blue, natural to glass coloured with this oxyd, to convert the whole into a soft light green. The green hue thus given is very slight and not disagreeable to the eye, and is hardly perceived unless the light pass through a great thickness of glass, as happens when a piece is held up edgewise. The quantity of zaffre necessary for this effect is extremely small, one ounce being sufficient for 1000 lbs. so that it is only $\frac{1}{1000}$ of the whole. It need hardly be added that when the sand, alkali, and lime, are very fine, and only these ingredients are used, no zaffre or corrective of bad colour is required. A great quantity of fragments and refuse pieces of glass is always collected during the working, and these are added again to the next fusion, but as glass

always loses alkali by the long continuance of fire and becomes thereby harsher and less fusible, too great a portion of these refuse bits (which of course undergo twice as long a fusion as the raw materials) will very sensibly alter the quality of the glass. As however they consist of glass already refined, the pot which contains much of them is much sooner brought to a working state, as it contains less glass-gall and impurities. These fragments of glass are reduced to gross powder by being heated red-hot, and immediately plunged into cold water, which splits them in every direction and enables them to be readily broken down. They should not constitute much more than a third of the whole composition. A very fine glass of this kind may be made by 200 parts of pretty good soda, 300 of fine sand, 33 of lime, and from 250 to 300 of the ground fragments of glass.¹

The manufacture of the common window glass though made by blowing, is carried on in a considerably different manner from that of the common flint-glass articles, as the object is to produce a large flat very thin plate of glass, which is afterwards cut by the glaziers' diamond into the requisite shape. The steps of the process could not be understood by mere description, but it may just be mentioned that the workman first takes a very large mass of glass on the hollow iron rod, and by rolling it on an iron plate and swinging it backwards and forwards causes it to lengthen by its own weight into a cylinder, which is then made hollow by blowing with a force of breath which only those that are used to the business can command, and is brought out to the requisite thinness. The hollow cylinder is then opened by holding it to the fire, which by expanding the air confined within it (the hole of the iron rod being stopped) bursts it at the weakest part, and when still soft it is ripped up through its whole length by iron shears, opened out into a flat plate and finished by annealing as usual.

Common green bottle glass is another kind, which indeed is by no means uniform in its composition, but is made almost entirely of sand, lime, and sometimes clay, alkaline ashes of any kind according as cheapness or convenience direct, and more especially of kelp in this country, of barilla, varec and the other varieties of soda in France, and of wood-ashes in many parts of Germany, and the like. To this too is sometimes added even the earth remaining from saline ashes, after the alkali and salts

¹ Encyclo. Method.

have been extracted by lixiviation, and in England flags from the iron furnaces. This refuse matter is still a flux of some power when in mixture with other earths, and it still retains a small quantity of salts which are not totally extracted. Bottle glass is a very hard well-vitrified glass, not very heavy relatively to its bulk and being fused at a very high heat, and from the impurity of the alkali and the abundance of earthy flux containing but a small proportion of real saline matter, it resists the corrosive action of all liquids much better than flint-glass. Besides being used for wine-bottles it is much employed for very large retorts, subliming vessels, and other processes of chemical manufacture, and here too it has the additional advantage of bearing as much as a pretty full red heat without melting or sinking down into a shapeless lump as the lead glasses would do. The following composition is given by Løysel as a good and cheap material for bottle glass, 100 parts of common sand, 30 of varec (a kind of coarse kelp made on the western coasts of France) 160 of the lixivated earth of ashes, 30 of fresh wood-ash or any other kind of ash, 80 of brick-clay, and any quantity, generally about 100, of broken glass. This composition gives no glass-gall.

A good bottle glass but nearly black and opaque has been made in France of another material which probably may be applied in many countries advantageously: it is the decomposed pulverulent basaltic earth found in the vallies of all basaltic countries. In France it abounds in the Vivarais, in Languedoc and Auvergne. The first glass of this kind appears to have been made in 1780 by a M. Ducros at the suggestion of Chaptal* who simply melted some of this basalt without addition in a glass-pot, and formed of it two very light, black, or rather deep yellow, shining, perfect bottles. In subsequent trials by another artist a mixture of equal parts of basalt and sand was employed, as being preferable to the basalt alone, and for a while there was a very considerable demand for bottles of this material, but the manufacture was abandoned owing to the want of uniformity in the ingredients, which made them often fail. The glass produced hereby was of a green olive.

It may not be uninteresting also to give the results of some experiments of M. Alliot on different mixtures of this basaltic earth. Seven crucibles filled with different mixtures were heated for eighteen hours in a common potter's

furnace (a glass-house not being at command, which however gives a less intense heat than the glass furnaces, and therefore if used in manufacture a greater effect might be allowed than was here noticed. The results were the following.

No. 1. contained the pure basaltic earth, and melted into a black, opaque glass, moderately well melted.

No. 2. was a mixture of $\frac{1}{3}$ basalt, $\frac{1}{3}$ of ashes, and $\frac{1}{3}$ of white quartz in powder. It was a milky, brilliant, coffee-coloured glass resembling fine porcelain.

No. 3. was a mixture, in equal parts, of basalt and common sand. It was moderately well melted, of a blackish-blue in mass, but in thin laminæ was of a yellow-green.

No. 4. was a mixture, in equal parts, of ashes and a volcanic granite. It melted well, gave a very fine dark yellow glass, of great lustre, and would have been very proper for bottles.

No. 5. contained $\frac{1}{19}$ of ordinary soda, $\frac{6}{19}$ of common sand, and $\frac{12}{19}$ of ashes, and gave a yellow-black glass interspersed with opaque blueish white veins.

No. 6. consisted of $\frac{1}{3}$ basalt, $\frac{1}{3}$ of refuse soda, and $\frac{1}{3}$ of sand. It gave a fine transparent green-yellow glass, very well melted, of a fine polish, and which would have been excellent for bottles.

No. 7. was simply the sand of the river Orb in the neighbourhood, which appeared by inspection to contain a large proportion of basaltic earth. It melted well and gave a very good bottle glass.

The analysis of basalt shews that it is very well fitted both for fusion *per se*, and to act as a flux of considerable power, for (as mentioned under that article) it consists of about 45 per cent. of silica, 16 of alumina, from 16 to 20 of oxyd of iron, 9 of lime, and from 2.6 to 4. of pure soda, of which the three last are all very powerful fluxes. Many other minerals contain even more soda, such as the Klingstein, which contains about 8 per cent. of this alkali, but having much less lime and oxyd of iron it is much less fusible. The colour of all the glasses into which basalt enters largely as a constituent is generally of a deep olive green passing to deep yellow, and in mass almost yellow, nor is it probable that this colour could be materially corrected. The glass is well ascertained to be specifically lighter than common green bottle glass but at the same time tougher, so as to bear harder blows without breaking, two

* Encyclop. Method. Article Verre.

very important advantages, and the quantity of alkali contained and that required to bring the whole to a workable state is so small as probably to enable this glass to resist all corrosive liquors, at least as well as any other known kind of glass.

Plate glass is that most beautiful and perfect glass of which all the kinds of mirrors and looking-glasses are composed, and of which the larger articles are wrought, not by blowing as every other glass article is, but by *casting* the melted glass on a flat table.

The Venetians were long in the sole possession of the art of making mirror-glass, but by them it was only manufactured by blowing, nearly in the way described under crown or window glass, and much of the common mirror glass is still prepared in this way.

In 1665 under the ministry of the great Colbert a company for *blown-mirror glass* was first established near Cherbourg in Normandy, on the plan of the Venetian manufacture, but the beautiful art of casting glass was invented in France about 1688, by one Abraham Thevart, and a company was soon established for this branch of manufacture which was first carried on at Paris, and soon after removed to St. Gobin, where it still exists in full activity, and undiminished reputation.

The plate-glass cannot be made by blowing of a larger size than about fifty inches to be perfect, but by the ingenious substitution of casting it may be made so large and at the same time so perfect, that scarcely any other limits can be set to the possible size of these plates than the heavy expence of the manufacture, in all its parts. As large plates as nine feet long, and wide in proportion, have been manufactured.

As this art of casting glass requires more care in the choice of materials and nicety in the processes of manufacture than most other branches of glass-making, some more detailed account may be given of it as carried on in France, as far as it can be understood without reference to plates.

The materials of the finest plate glass are white sand, soda, and lime, to which are added manganese and zaffre, or any other oxyd of cobalt for particular colouring purposes, which will be presently described. The sand is of the finest and whitest kind, and is previously passed through a wire sieve of moderate closeness into water where it is well stirred about and washed till all dirt and impurity is got rid of. The sharpest grained sand is preferred,

and indeed it is found that the grains of moderate size melt with the alkali sooner than either the very fine dust or the larger fragments, in the former case the sand clotting together without mixing freely with the alkali, and in the latter the grains taking a longer time to dissolve on account of their bulk. The alkali used here is always soda, and there seems good reason to prefer this to potash, as glasses made with soda are found to be softer and to flow thinner when hot, and yet to be equally durable when cold, and in casting a large plate of which the perfection is to be without streak or bubble it is obvious of how much importance it must be to have it flow extremely liquid from the pot. Besides, the neutral salts with the basis of soda which constitute the glass-gall in this instance, such as the muriat and sulphat of soda, appear to be dissipated more readily by the fire than the corresponding salts of potash. The soda used here is considerably pure, or such as is separated from the rough ashes of barilla, and other soda plants by lixiviation.

Lime is of considerable use here and adds much to the fusibility of the other materials, supplying in this respect the use of litharge in the flint-glass. Too much lime however impairs the colour and solidity of the glass. About $\frac{1}{15}$ of the whole is as much lime as can be used with propriety, and some use as little as $\frac{1}{24}$.

The colouring or rather decolouring substances used are *azure*, or cobalt blue, and manganese. The latter is here in the state in which its effect is that of giving a slight red tinge, which mixes with the blue of the cobalt and the natural slight yellow of the other materials, and altogether are found when properly proportioned to neutralize each other so that scarcely any definable tint remains.

Besides these ingredients there is always a great quantity of fragments of glass arising from what is spilt in the casting and the ends cut off in shaping the plates, which are made friable by quenching in water when hot and used in this state along with the fresh materials.

With regard to the proportions of the ingredients very considerable latitude may be allowed. The quantity of soda is a good deal more than necessary merely to produce a good glass, as one of great fusibility is required. The following doses are found to produce a very fine glass: 300 lbs. of sand; 200 lbs. of soda; 30 lbs. of lime; 32 ounces of manganese; 3 ounces of azure; and 300 lbs. of fragments of glass.

It does not appear whether or not any other fluxes are used, though there seems to be some secrecy observed in this respect at the manufactory of St. Gobin. It is constantly asserted and with much probability, that borax is also used in small quantity. This is in itself highly probable, as the very thin watery fusion which this flux gives to vitrifying matters seems peculiarly wanted in glass intended to be cast, and probably this addition would enable the manufacturer to use potash with as much advantage as soda where it happened to be cheaper.

Of the above materials the sand, soda, lime and manganese are first mixed together with more care than for ordinary glass, and are fritted in small furnaces built for this express purpose, the heat being gradually raised to a full red-white, and kept at this point with frequent stirring till the materials undergo no further change, nor give any kind of vapour. The azure and the glass fragments being already perfectly vitrified are not added till just at the end of the process which lasts about six hours.

The glass-house for this manufacture differs in several particulars from the common houses for blowing glass. The furnace at St. Gobin is about 18 feet long and 15 wide, made of good bricks. They are particularly distinguished from the common furnaces by containing two kinds of crucibles, the larger ones called *pots* are in the form of an inverted and truncated cone, and in these the glass is melted. The other set of crucibles are smaller ones called *cuvettes*, the capacity of which is not more than a sixth, or where very large plates are cast, a third, of the pots, and are kept in the furnace empty, but quite hot, till the glass is ready for casting, when they are filled out of the pots, and drawn out of the furnace on an iron cradle to the heated table or bed on which the glass is cast. Both the pots and the *cuvettes* are of the same material, of good refractory clay. Another essential part of this furnace is the flat table (of which there is one corresponding with each pot) on which the glass is cast. These tables are of smooth thick copper plate about ten feet by six, strongly supported by masonry; and contiguous to each table on the same level are flat ovens, heated from underneath, upon which the glass when cast and sufficiently cooled, may be slid without difficulty from off the copper table and there annealed. The tops of the flat ovens and the tables are on a level with the corresponding opening of the furnace whence the *cuvettes* are withdrawn. The fuel used is

wood, and the kind which makes the largest and brightest flame, but without giving much resinous smoke is preferred. It requires about thirty-six hours of strong heat from the time of filling the pots till the glass is fit for casting.

The process of filling the pots and the appearances that take place in the melting materials, the rising of the glass-gall, refining, &c. need not be described, being the same as in other glass-making.

When the glass is thoroughly melted and fine, the proceedings are in a general way as follows: the *cuvette* (which has been previously emptied of all the loose glass and foulness which may have adhered to it and again made quite hot in its place in the furnace) is filled in the following way; the workman takes a copper ladle about ten inches in diameter and fixed to an iron handle seven feet long, plunges it into the glass pot (the contents of which have been previously skimmed carefully) brings it up full of the melted glass, and empties it into the *cuvette*, the ladle being supported at the bottom by a strong iron rest, held by two other workmen, lest the red-hot copper should bend and give way with the weight of the glass within. The *cuvette* being filled by repeated lading is then suffered to remain in the furnace for some hours, that the bubbles formed by this disturbance of the glass may have entirely disappeared, and the samples taken out from time to time become quite clear and limpid. The door of the furnace is now opened, the *cuvette* is slid out and pulled upon a low iron cradle and immediately drawn on to the side of the copper table, previously heated by hot ashes and wiped quite clean. The *cuvette* full of the melted glass is then carefully skimmed by a broad *fabre*, or copper blade set in iron, which carries off with it every impurity at the surface. The reason of using copper for this as for the ladle and casting table is that it does not discolour the hot glass as iron does. The *cuvette* is then hoisted up by a tackle and iron chains, and overset upon the copper table, on which a thick flood of melted glass flows and spreads in every direction to an equal thickness. It is then made quite smooth and uniform at the surface, by passing over it while still quite hot a heavy hollow roller or cylinder of copper made true and smooth by turning after it is cast, and weighing about 500 lbs. At the same time the empty *cuvette* is returned by the iron cradle to its proper place within the furnace. The edges of the copper table overhang a reservoir of water into which the

waste glass falls in drops, and is used for the next melting. The number of workmen required for the whole process of casting is at least twenty, each of which has his separate employment.

The plate being cast, the inspector examines whether there are any bubbles on any part of the surface, and if found, the plate is immediately cut up through them. The plate being now so far cool as to be stiffened is slid by an iron instrument from the casting table to the contiguous annealing oven previously well heated, and is carefully taken up and ranged properly within it. Each oven will contain six entire plates, and when full, all the openings are stopped with clay and the plates allowed to remain there for a fortnight to be thoroughly annealed.

When fit to be taken out of the annealing oven they are sent away to receive all the subsequent operations of polishing, silvering, &c. but first their edges are cut smooth and squared. This is done by a rough diamond which is passed along the surface of the glass upon a square ruler in the manner of glaziers, and made to cut into the substance of the glass to a certain depth. The cut is then opened by gently knocking with a small hammer on the under side of the glass just beneath, and the piece comes off, and the roughnesses of the edges are removed by pincers. The plate is then finished as far as the glass-house business is concerned and is carefully removed to the warehouse.

The subsequent operations of polishing and silvering may here be added in a few words.¹ The plate is first exactly squared by the diamond in the way mentioned above, and minutely examined as to any flaws or faults which may be found. The next step is to grind off all the inequalities and roughnesses of surface previous to the polishing. This is done on both sides by sand and water. For this the plate is laid on a thin plate of free-stone or on a long wooden frame, of about the same size with it and cemented strongly thereto by Paris plaster. Another plate is also cemented in the same manner and laid upon the lower plate, and wet sand is interspersed between the two. The plates are then made to rub against each steadily and evenly by a kind of hand mill, the wheel of which is worked by a man, or sometimes in large plates by two men, who can regulate the pressure of one on the other as it may be judged proper.

In proportion as the surfaces of the plates wear down the sand is used successively finer, being previously sifted and sorted for the purpose. In general the workmen avoid rubbing two absolutely rough surfaces on the other for fear that the great jarring of the friction should produce flakes and flaws in the glass, but a half ground plate is rubbed on a fresh surface and so on successively.

When one side of the plate is done, the plaster which cemented it is picked off, the plate turned, and the opposite side ground in the same manner. Towards the end of the grinding the pressure is increased by loading the upper plates with flat stones of different thicknesses. This process lasts about three days, and great attention is paid to finish them with surfaces perfectly flat and parallel, which is determined by the ruler and plumb-line. The ground surfaces are now uniformly worn by millions of scratches, and therefore nearly opaque unless held up to the light, but still very far from having the requisite fineness to receive the polish. This further grinding is done by emery of different degrees of fineness, the preparation and sorting of which is done in the following very simple manner. A large quantity of rough emery is put into a vessel with water and strongly stirred about till the whole is mixed. But as emery is absolutely insoluble in water the whole will again be deposited in successive layers, the coarsest particles sinking first, and the others afterwards in the inverse degree of their fineness. By standing about twenty minutes and then pouring off the supernatant liquor, the latter holds suspended only the very finest particles which again separate by rest for a longer time. More water is then added to the vessel, the emery stirred again, and now allowed to remain at rest only for fifteen minutes, and the supernatant turbid liquor again poured off. This furnishes by rest an emery of the second degree of fineness. The same is repeated twice more at the different times of about five minutes and half a minute, by which two other sorts are obtained. The wet emery from all these liquors is separately heated over a stove to evaporate the water, and when nearly dry is made up into balls in which state it is distributed to the workmen.

The plates are then further ground on both sides with two or three emerys, beginning with the coarsest and are finished with great care. They are now perfectly even, with a deadening or opacity on their surface, but so fine that no

¹ Encyclop. Meth. Journ. and Polytech. pt. 5.

scratches can be perceived. In this state they are again examined, and if any material defects still remain below the ground surface, they are cut up with the diamond into smaller plates with the greatest economy possible, the diamond now dividing them with much greater ease than before, both on account of the quantity of substance of glass removed and the uniformity of the surface.

The next process is that of polishing both surfaces to that perfect brightness which is seen in finished mirrors, so that the rays of light may pass through unimpaired to the silvering on the posterior surface and be reflected again from thence according to the laws of catoptrics. The substance used to give this last polish is colcothar, imported from this country and called *rouge d'Angleterre* or *Potée*. It is the residue left in the retorts of the aqua-fortis makers, and when well washed and levigated consists of little else than a red and perfect oxyd of iron.

The polishing instrument is a block of wood covered with several folds of black cloth with carded wool between each fold so as to make a firm elastic cushion. This block has a handle for the workman to hold; for the whole of this part is done by hand and not by machinery, as the latter would work too uniformly, and not allow of that variation of pressure and those finishing touches which are required to bring every part of the glass to exactly the same height of polish. But to encrease the pressure of the polisher without fatiguing the workman, the handle is lengthened by a wooden spring bent to a bow and three or four feet long, which at the other extremity rests against a fixed point in a beam placed above. The plate being fixed on the table by plaster he then moistens the polisher with a wet brush, covers it with colcothar and begins his operation by working it backwards and forwards over the surface of the plate. Much practical skill and dexterity is required to give an uniform and high degree of polish over the surface of a large plate, as it must be done by separate portions and the finishing touches given with great care. The glasses of moderate size are completed in four portions from corner to corner, the centers of which intermingle so as to leave no part untouched, but the larger glasses require additional polishing in the center. When one side is completed and the reverse is about to be done, the polished side, now the undermost, is entirely covered with the red colcothar to prevent the dazzle reflected from the white plaster which would

prevent the workman from judging so accurately of the state of the surfaces on which he is employed. When both sides of the glass are thus brought to the same perfection of polish, the operation is finished by inspecting the glass, first cleaning both surfaces, and laying it, each side alternately upwards, upon a dark blue or black cloth admitting only a moderate light, and if any part appear less highly finished than the rest it is retouched by a small hand-polisher and colcothar as before.

When a number of smaller pieces of glass, such as are used only for chamber or similar mirrors are to be polished, they are laid together on the table and several of them polished at a time. But as these consist of pieces often of unequal thickness, though their surfaces have been rendered perfectly flat by the previous grinding, if they were simply placed side by side and fixed on the table by plaster as usual, the polisher would not work well over such a variety of heights, and would act chiefly on the edges of each piece of plate. Therefore they are all first arranged on a large smooth plate, finished all but the polishing, and previously wetted, and plaster is poured upon them by which they are fixed together, and then when taken off, the surfaces which were in contact with the plate are perfectly level with each other, and the polishing goes on with the same ease as on an entire plate.

What is termed *silvering* of mirrors, is applying to the posterior surface a coating of quicksilver, which metal when perfectly bright and brilliant reflects the rays of light with great accuracy and beauty. But as this fluid metal could not be alone applied without great inconvenience, it is first made to adhere by a partial amalgamation to the surface of a sheet of tin-leaf, and then by the help of pressure is applied closely to the glass in a very thin lamina. It is therefore properly a thin sheet of tin fully impregnated with mercury which is the reflecting surface.

The management of the silvering is extremely simple. A perfectly flat slab of smoothed freestone (or sometimes of thick wood) a little larger than the largest plate, is inclosed in a square wooden frame or box open at top, and with a ledge rising a few inches on three sides and cut down even with the stone on the fourth. A small channel or gutter is cut at bottom of the wooden frame, serving to convey the waste mercury down into a vessel below, set to catch it. The slab is also fixed on a centre pivot, so that one end may be raised by wedges (and of

course the other depressed) at pleasure when working freely in the box.

The slab being first laid quite horizontal, and covered with grey paper stretched tight over it, a sheet of tin-foil, a little bigger than the plate to be silvered is spread over it, and every crease smoothed down carefully; a little mercury is then laid upon it, and spread over with a tight roll of cloth, immediately after which as much mercury is poured over it as will lie on the flat surface without spilling. That part of the slab which is opposite the cut-down side of the wooden frame, is then covered with parchment, and the glass plate is lifted up with care and slid in (holding it quite horizontally) over the parchment, and lodged on the surface of the slab. The particular care required here is, that the under surface of the glass should from the first just dip into the surface of the mercury (skimming it off as it were) but without touching the tin leaf in its passage which it might tear. By this means no bubbles of air can get between the glass and the metal, and also any little dust or oxyd floating on the mercury is swept off before the plate without interfering. The plate being then let go sinks on the tin-foil, squeezing out the superfluous mercury, which passes into the channel of the wooden frame above-mentioned. The plate is then covered with a thick flannel, and is loaded over the whole surface with lead or iron weights, and at the same time is tilted up a little, by which still more of the mercury is squeezed out. It remains in this situation for a day, the slope of the stone slab being gradually increased to favour the dripping of the mercury. The plate is then very cautiously removed, touching it only by the edges and upper side, and the under side is found uniformly covered with a soft pasty amalgam consisting of the tin-leaf thoroughly soaked with the quicksilver, and about the thickness of parchment. It is then set up in a wooden frame, and allowed to remain there for several days, the slope of its position being gradually increased, till the amalgam is sufficiently hardened to adhere so firmly as not to be removed by slight scratches, after which the plate is finished and fit for framing.

It is a considerable time before the amalgam has acquired its utmost degree of hardness, so that globules of mercury will often drip from new mirrors some time after they have been set up in rooms, and violent concussions of the air, such as from the firing of cannon, will often detach portions of the amalgam. These can

never be perfectly replaced by any patching, as the lines of junction with the old amalgam will always be marked by white seams seen when looking into the glass.

Of working Glass with the Lamp and Blow-Pipe.

A great variety of small articles of glass for philosophical purposes, such as thermometers and barometers, and many ingenious toys, are made out of glass tubes by the blow-pipe, and some short account of the general method of proceeding may here be added.

The usual apparatus of the glass lamp-blowers is very simple. It consists of a solid table at the bottom of which is fixed a double bellows with a foot-board, that the artist may work it with his foot and keep both his hands at liberty, whence proceeds a pipe which conducts the blast to the lamp, which is a large bundle of cotton thread lying in a tin vessel of a horse-shoe shape and fed with lumps of tallow heaped up beside it. These are from time to time drawn forwards into the flame, to keep up the combustion. A small chimney hangs a little way over the lamp to carry off the smoke. The blast-pipe comes up in front of the table where the artist sits, and drives the jet of flame in a contrary direction to his body, so that he is not in the least incommoded by it. All the rest of his apparatus consists of an assortment of glass tubes, of different bores and thicknesses of glass (made at the glass-house, by pulling out rather suddenly a bottle of blown glass when still quite soft) and two or three very simple iron tools, such as small forceps, files, &c. Any other method of working the blow-pipe may be adopted that will give a very large and powerful flame. The flame when in full vigour is a jet of fire about four inches long, not sharp-pointed, but like a blunt rounded spear-head, which near its extremity is of a clear light blue, and beyond, of a pale yellow. The blue part is the hottest. As general rules for managing the working, the tubes should never have any moisture introduced into them, and should be well dried on the outside before working. They are to be heated gradually (with more care in proportion to the thickness) first by being held in the flame of the lamp without blowing, and then at the edge of the outer yellow part of the jet of flame, and slowly brought to fusion. The flame is strong enough to bring to a very white-red heat a solid mass of glass about as big as a child's playing marble, or even larger, which when blown out very thin, will make a bulb of the capacity of full three

ounces, and this is nearly the extent of the power of the common lamp-blowing. But the bulbs for thermometers, or other philosophical purposes are much less. Two or three of the commonest operations may be described.

To seal a tube hermetically, if small, it is sufficient to hold it in the flame for a little time slowly turning it round, when the end will melt, and falling in, will close the cavity with a neat button. This may be assisted by pushing the softened ends in towards the common center with an iron needle. But if the tube be very large, this button would be too clumsy, and being thick would be in danger of breaking on cooling. It is therefore necessary to lessen the quantity of glass, which is done in the following way: soften the end of the tube in the flame, and apply to it a piece of another tube of nearly the same size (fragments of tubes being always abundant in this business) which will stick firmly to it. Then soften the tube to be sealed a little higher up than the point of juncture, and pull the two slowly in contrary directions till they separate. The tube will then draw out at the heated part into two short thin funnels, and a little turning and management of the flame will readily seal that which is wanted, leaving the joined ends and about half an inch of the lower part of the tube on the waste piece.

To bend a tube, if of a narrow bore and the glass is pretty thick, it is only necessary to hold it in the weaker part of the flame, and soften it for about an inch or two of its length, and bend it slowly into the required shape. In this way barometer tubes are bent. But if the tube be wide, and the glass thin, this way of bending entirely destroys the cylindrical form of the bore at the bent part, making a double flattening. To avoid this, first seal up one end of the tube, and then whilst bending it at the required part, blow steadily and gently into the open end, and the pressure of the breath will counteract the falling in of the sides of the bending portion, and keep the bore cylindrical. The closed end is then cut off by the file, to do which make a deep scratch with one edge of a fine three-cornered file on the part intended to be cut, then break the tube with a smart pull in that direction in which the scratched part will be outermost, and it will separate in general with great accuracy at this point.

To join two tubes, heat them both in the flame, and apply them together when white hot, turning them round to finish the consolidation, or else to avoid the thick ring of glass which this produces, previously close one end of one

tube, and when the two are fully joined blow into the open end of the other tube, and pull them out a little at the point of juncture, till an equal cylinder is formed.

To form a bulb (of a thermometer for example) choose a tube of a very equal bore, seal the end in the usual manner, and to collect a greater mass of glass at the end, press upwards on it while quite hot with any iron instrument, so as to consolidate and shorten it a little; let it remain in the hottest part of the flame till the lump of glass is quite white hot, then remove it, put your lips to the open end without loss of time, holding it with the hot part lowest, and blow moderately and steadily. The lump of hot glass will immediately open into a bulb, the size of which can be regulated at pleasure.

Glass may be spun out into threads of almost indefinite minuteness by means of the blow-pipe. When no thicker than fine hair, it is extremely flexible and elastic, and if still finer it may be wound almost like common thread without breaking. The way of doing it is very simple. A piece of glass tube is heated in the lamp, and the end drawn out into a thread by means of another piece of glass cemented to it. When a fine thread is once drawn, the end is carried round a reel or wheel two to three feet in diameter, and by turning the wheel and continuing to heat the tube, an endless thread is drawn out, winding round it as long as the artist pleases or the glass lasts. The quicker the wheel revolves, and the hotter the glass is kept, the firmer is the thread, which may thus be made as delicate as a single silk-worm's thread, with extreme flexibility. Different coloured threads are made in this way by using very deeply coloured glasses instead of common glass.

* * *

A singular change occurs in the texture of glass, more particularly of green bottle glass, made only of sand, lime, and saline ashes, when exposed for some time to a moderate red heat, or any higher temperature, but below its melting point. This is peculiarly observable when it has been in contact with sand, and hence it frequently takes place in green glass retorts long exposed to a high heat in sand-bath distillations. Neuman appears the first who noticed this change, which was afterwards examined more at large by Reaumur, and from the porcellaneous texture which the glass assumes when thus changed, it has been commonly called *Reaumur's porcelain*. This ingenious philosopher had the idea that much advantage might be made of this fact in rendering glass much

tougher and less liable to crack from changes of heat and cold. No use however has been made of it in manufacture, but as a curious chemical or physical phenomenon it deserves further notice.

Dr. Lewis made the following very valuable experiments on this substance.^c A number of pieces of common quart bottles were put into crucibles with white sand poured over them, and put into a proper furnace where they were heated for many hours, and pieces withdrawn from time to time to examine the progress of the change. The pieces that were taken out, after many hours heating, but *below redness*, did not appear to have suffered any change whatever. In a low red heat the change went on though very slowly, but in a strong red heat approaching to whiteness, just not sufficient to melt the glass, the change went on pretty fast, and in two hours the glass had assumed the appearance of porcelain, the change beginning at each surface and spreading gradually to the middle.

The glass first became blueish on the surface, and, when held to the light, yellowish, and with a very sensible diminution of its transparency. After this it gradually became white and opaque, and the texture was no longer vitreous, but fibrous, and the fibres disposed nearly parallel to each other. By degrees the glass became throughout opaque and fibrous, and the colour of a dun white; the fibres were arranged regularly from the sides to the middle, where the fibres from the two sides meeting, formed a kind of partition, in which occasionally were pretty large cavities. A longer continuance of fire induced a further change of texture, the fibres became divided or cut into grains at the outer ends and gradually through their whole length, and the whole substance changed in texture from *fibrous* to *granular*, like common porcelain. By a still further continuance of fire the grains, at first fine and glossy, grew larger and duller, from being very compact became porous, and at last a friable substance like a slightly cohering mass of white sand, not easy to be distinguished from the sand in which it was imbedded.

Glass thus changed whilst it remains in the fibrous state, is considerably tougher and harder, so as to give abundant sparks with steel, which common green bottle glass will hardly do, to cut all common glass with ease, and scarcely to be scratched by the file. It will bear also to be plunged suddenly from freezing to boiling

water, without cracking, and at the same time its texture is so dense that no acrid liquors whatever either corrode it or transude through it. The circumstance which the most prevents its use in manufacture is, that though the inner texture is fine and white, the outer is coarse and dirty-looking. When the heat is so long continued that the texture changes from fibrous to granular, it again becomes soft, no longer gives fire with steel, and loses its cohesion.

Another important circumstance to be observed is, that when this fibrous porcellaneous glass is exposed to a very strong heat it melts into a semi-transparent mass, drawing out in strings, which on breaking are now no longer fibrous, but have *returned to the vitreous state*, and at the same time again becomes no harder than the glass from which it was originally made. However it does not melt so easily as the glass itself, and the longer it is cemented the more difficult of fusion it becomes, so that the granular porcelain requires a much higher heat for melting than the fibrous.

Dr. Lewis repeated the experiments, imbedding the glass in a variety of substances instead of sand, such as bone-ash, charcoal, chalk, &c. but in all the change of texture was the same, the outer colour alone being affected. He then heated the glass by itself, being stuck up with a little luting in the middle of the crucible, and therefore touching nothing with the part above the luting. The same change however took place, though more slowly, and with some inconvenience from the falling in of some of the pieces when softened by the heat. The sand therefore has little other effect than to support the glass during the process, and prevent it from losing its shape. Another important fact to the explanation of the cause is that the glass does not sensibly lose or gain weight in the whole conversion from the vitreous to the fibrous state.

Mr. Gregory Watt, in his most valuable paper on Basalt,^d very happily brings this porcellaneous change of glass as an illustration of his important position, namely, that bodies whose fibres have a natural tendency to a crystalline arrangement, or a polarity, when vitrified by a sufficient heat and cooled hastily in the vitreous state, are able subsequently to return to their natural crystalline arrangement of fibre when exposed to a heat merely sufficiently to soften the texture, though not enough for fusion. This, in the instance of basalt, he shews by the singular crystallizations formed in the cells of

^c Commerce of the Arts.

^d Phil. Trans. for 1804.

fused basalt, long after it had lost the liquidity of fusion. The circumstance of no material change occurring in the weight of glass by this conversion into the fibrous state, shews incontrovertibly that it cannot be owing either to any thing gained during the process, nor to any material loss of the alkali, and this is also rendered manifest by its return to the vitreous state and vitreous qualities when again melted. This too may again be porcellanized in the same way, and again be melted into glass, and so on alternately.

Glass has been often found crystallized quite at the bottom of the pots, and in places where it has cooled undisturbed for a length of time. This is particularly the case in that mass of refuse and spilled glass, with ashes, melted drops from the clay of the furnaces and pots, &c. which falls down behind the pots in the furnace.* This is generally raked out, but part of it remains, and when the fire is let to go out, and the furnace is become useless, these crystallizations are usually found here. They are found in all kinds of glass, but less often in the fine flint and the very saline glasses, than in the coarser green and crown glasses.

* * *

OF COLOURED GLASSES.

The metallic oxyds when mixed with any of the glasses, dissolve in them with ease at a melting heat, and always change the colour more or less, sometimes producing very beautiful compounds, which when well prepared, have a lustre and richness of colour strongly resembling that of the natural gems, though in an inferior degree. The business of making these coloured glasses or artificial gems, is carried on to a very great extent in the manufacture of a variety of ornaments, and though much of the management remains a secret in the hands of the artists, a good deal of valuable matter has been made public by the labours of Neri,^a Kunckel,^b Margraaf,^c Fontanieu,^d and many other practical chemists.

It is very easy for any person at all used to chemical experiments to repeat most of these in the small way, with sufficient success to satisfy himself of the leading facts, though for the purpose of manufacture more care in the choice and preparation of the materials, and a greater length of time in the melting part is required than most experimenters choose to bestow.

It may be premised too that the art of making coloured *Enamels* is essentially the same as that of coloured glasses, the chief difference being

that in the former case the *ground* or vitreous substance that receives the colour is an opaque enamel glass, and in the latter a clear transparent glass. The way of preparing the enamel ground is described under that article. The colouring power of the metallic oxyds is also in many instances much affected by the degree of heat to which they are exposed, and to the other ingredients with which they are mixed, and hence arise a good many precautions and niceties of management, many of which are only known to the practical artist. There seems good reason to suppose that much of this difference depends on the degree of oxygenation in which the colouring oxyd is left after the action of fire, or of the other ingredients. The phenomena that occur in the use of manganese have already been described, and something similar happens in using the oxyds of iron and silver. Sometimes a metallic oxyd may be so nearly reduced to the reguline state, as not to be perfectly soluble in the glass, but only suspended in it. This happens occasionally with the oxyd of copper, which when perfectly oxydated gives a fine blueish-green, but when nearly in the metallic state produces a brown-red and not perfectly transparent glass. There is also a mutual action of the oxyds upon each other, so that the glasses in which oxyd of lead enters, will not receive a red colour by iron, an effect which is not produced with the merely alkaline glasses. Much remains to be done on this very curious and entertaining subject of the colouring power of metallic oxyds, and it is only by a well-conducted scientific series of experiments that the perplexing intricacy of many of the receipts of the articles on this subject can be reduced to certain rules.

In making coloured glasses to resemble artificial gems, the glass which is to receive the colour (which is often called *crystal*) ought to unite the qualities of great purity, lustre, and hardness, together with a sufficient fusibility to melt at a moderate heat those oxyds that are in danger of being decomposed by a high temperature. A vast variety of receipts have been given for such a glass, and it appears that several sorts are actually in use according to the price and object of the manufactured article. The glasses that possess the greatest lustre and are at the same time easily fusible, are unquestionably those in which the oxyd of lead enters very largely, and it appears that many of them are little else than oxyd of lead vitrified with a much smaller proportion of silica than is used

^a Dartigues J. Phys. tom. 59.

^b Art. de la Verrerie.

^c Mem. Acad. Berlin, 1780.

^d Encycl. Method.

even in flint-glass, or any other species. To these borax is an important addition, and often arsenic and other fluxes are added. But it unfortunately happens, that the lead-glasses are at the same time the softest, and scratch with the greatest ease. Hence it is the perfection of this art to find a compound, or manage any of the known compounds, in such a manner as to unite both lustre and hardness; in the former, the natural gems (the diamond excepted) may be very nearly equalled, but not in the latter.

Many of the older artists have had the idea that a harder glass would be obtained by making rock crystal the siliceous basis than sand, flint, or any other stone of this genus. But this seems totally unfounded, for when once dissolved in a flux of any kind, the hardness of rock-crystal is irrecoverably lost, as it is not an inherent property of this particular species any otherwise than as depending upon its natural aggregation, which of course is destroyed. Perhaps it may be somewhat purer than the finest sand, or than powdered gun-flints, since these (the latter at least certainly) contain a very minute portion of iron, which possibly, though not very probably, may a little affect the very finest colours. It is rendered friable by being heated red-hot and quenched in water in the same way that gun-flints are. It should then be ground in a hard stone mortar, or in a mill, and not in any metallic mortar.

A few of these glasses may be here given from the directions of M. Fontanieu.

No. 1. Mix 20 parts of litharge, 12 of silex, 4 of nitre, 4 of borax, and 2 of white arsenic, frit them in a crucible and afterwards melt, then pour the whole into water, separate any revived lead that may be found, and melt again.

No. 2. Mix 20 parts of cerusse, 8 of silex (powdered gun-flints) 4 of carbonat of potash, and 2 of borax. When melted, pour into water, and re-melt in a clean crucible.

No. 3. Mix 16 parts of minium, 8 of rock-crystal in powder, 4 of nitre, and 4 of carbonat of pot-ash; melt and re-melt as before.

No. 4. Treat as above 24 parts of borax, 8 parts of rock-crystal, and 8 of carbonat of pot-ash.

No. 5. Make a quantity of liquor of flints by fritting together 3 parts of alkali with 1 of rock-crystal, which dissolve in water, and saturate with dilute nitric acid. Edulcorate and dry the silex which precipitates, and which is then in a very fine impalpable powder. Then melt it in a crucible with $1\frac{1}{2}$ its weight of very fine cerusse, and pour the glass into water. Then

break it down and melt it with $\frac{1}{2}$ its weight of borax, and pour into water as before. Lastly melt this latter product with $\frac{1}{2}$ of nitre, and the result will be a very fine hard glass of extreme lustre.

Of the above glasses, No. 1. will be extremely soft and fusible, on account of the large proportion of flux, and it requires a very good crucible to withstand the corroding effect for a number of hours. The crucibles are found to stand better if they are first lined with any common glass without lead, for which purpose a little of the glass, No. 4, may be moistened with water, rubbed over the inside of the crucible, slowly and thoroughly dried and heated red-hot before the mixture is added, which will give it an uniform glazing. Silex requires to make a perfect and sufficiently workable glass from $1\frac{1}{2}$ to twice its weight of oxyd of lead, and a glass of this kind with a smaller quantity of oxyd of lead and a little other flux, will be very hard and brilliant, and will imitate the diamond when properly set, more than most other compositions.

The length of time required for fusion of the coloured glasses, appears to be for the hard glasses or *pastes*, at least twenty-four hours, but the softer mixtures are thoroughly compleat in a few hours. In the glass, No. 4, the silex is first directed to be reduced to the state of the greatest purity, and the most impalpable powder, by previous fusion with an excess of alkali, and precipitation by an excess of acid. It is seldom however that such extreme nicety of preparation can be required, and probably finely powdered flints would answer as well, or even fine sand. The process of pouring the melted glass into water, and re-melting, is used to mix the ingredients thoroughly, and is found by experience to have its use.

We shall now proceed to the colouring matters which (one excepted) are all metallic oxyds. We shall first mention the effect of the several metals individually, and then the method of producing the particular colours.

Of Gold. This metal in the state of great division, and oxydated, has long been celebrated for giving to glass a most exquisite purplish-red resembling the ruby, and nearly equalling it in beauty. It is both the most expensive and the most splendid of all the artificial gems or coloured glasses, but the management seems to be extremely difficult to ensure the compleatest and most uniform success, principally, as may be supposed, from the great tendency of gold to assume the reguline state by mere heat, by any

carbonaceous vapour, or by hydrogen. The most celebrated and the commonest preparation of gold for giving a purple to glass and porcelain, is the *purple precipitate of Cassius*, or gold precipitated from its nitro-muriatic solution, by, and together with, the oxyd of tin. The usual way of making it is, to dilute very largely a solution of gold in aqua-regia (formed by about 3 parts nitric and 1 muriatic acid) and add to it drop by drop a very dilute nitro-muriat of tin, well saturated with this metal. The liquors immediately become of a purplish red colour (like Port wine and water) and by standing, a precipitate of this colour with some varieties of shade, slowly subsides. A similar precipitate also takes place with the nitro-muriat of gold and the pale muriat of tin, and also with great certainty by immersing a stick of tin in the dilute solution of gold. Though the change of colour always takes place when the nitro-muriat of tin is used, the precipitate sometimes fails to separate without any apparent reason. This substance is a most intimate mixture of the oxyds of tin and of gold, but the precise state of oxygenation of the tin is not well known, nor its exact use. It is certainly not essential to give the purple-red tinge to glass, since many other preparations of gold will produce it, in which not an atom of tin enters. Possibly the tin enables the gold to bear a longer continuance of heat, and a higher temperature, without reduction.

The precipitate formed by *metallic tin* and the solution of gold, may be supposed to be at a lower state of oxygenation than where the nitro-muriat of tin is employed, and probably it is always useful to add a little nitre to the powder before mixing to prevent the partial reduction of the gold by the heat. Neither copper nor silver, in small quantities, appear to injure the colouring power of gold.

Another preparation of this metal used in glass and porcelain colours, is the *fulminating gold*, prepared by precipitating this metal from its nitro-muriatic solution by ammonia. This preparation is known to explode most violently when raised to somewhat less than a tin melting heat, or even by moderate friction, but if kept for some time at a much lower temperature, being previously mixed with a fixed alkali, it loses its fulminating property, and may be safely used. A more manageable preparation of gold is the precipitate from the nitro-muriat of gold, by carbonat of potash, which is a brown-red or yellowish powder, and is not fulminating pro-

vided the solution of gold be made with the muriatic acid, and not muriat of ammonia, for it is the presence of ammonia that is essential to the fulminating property. For the fine porcelain carmines, this carbonated oxyd of gold, as well as the decomposed fulminating gold, is mixed with luna cornea, and then with the proper quantity of saline flux, in which nitre and borax usually enter.^a The colouring power of these simple oxyds of gold, is nearly twelve times as strong as that of the purple precipitate, another proof that the tin does not of itself add to the body of colour. An ingenious way of producing a most intimate admixture of the oxyd of gold with flint, is to add the nitro-muriatic solution of the metal to the liquor filicum, or filicited alkali, and, if necessary, to add a further quantity of any acid to saturate the alkali. The flint is then precipitated in very intimate combination with the gold, and when washed and dried, is fit to be used as a colour, when mixed with nitre and borax or any other flux.

Whenever the purple precipitate by tin is used, it appears to be the practice to add about $\frac{1}{8}$ of its weight of the perfect white oxyd of antimony by nitre, or else of the glass of antimony. This naturally gives a yellow, and it seems by experience to be a very important ingredient in the composition of the fine ruby glass. The particular rules for managing the fire in making this nice and difficult preparation, are known only to practical artists, but it can hardly be doubted that the peculiar risk is of giving too much heat, and thereby of destroying the colour altogether. All kind of smoke and other vapours should also be avoided. The finest ruby glass is said to come out of the crucible, when compleat, quite colourless, but to assume its peculiar exquisite tint as it cools.

Of Silver. All the oxyds of silver give naturally a yellow to vitrescent mixtures, which appears to be very pure and beautiful, but is not often used in the coloured glasses on account of the ease with which it is destroyed by too much heat. It seems to be chiefly used in the tender porcelain and enamel colours, where the eye of the artist can always be upon his work, and the heat is lower and much more manageable. In the latter case the oxyd of silver is generally mixed with a small quantity of alumine. The phosphat of silver formed by adding the nitrat of silver to the phosphat of soda, is also employed.^b

Of Iron. The shades of colour produced by

^a Brogniart, Journ. de Mines. No. 67.

^b Clouet.

the oxyds of iron are very numerous. In the general account of glass-making it was observed that a very small portion of iron fully vitrified with a large body of glass gave different shades of green and yellow, and to this the colour of common green bottle glass seems to be owing. A larger dose of iron gives a yellow after thorough vitrification, and a still larger gives a brownish black, which seems to be only a yellow very much concentrated, since this latter colour is again produced by diluting the brownish-black with a greater quantity of uncoloured glass. The oxyds of iron also produce a red upon enamel and porcelain, but as it appears, this is only owing to imperfect vitrification, that is to say, it is only red as long as it is merely *suspended* in the glass flux in a state of extreme division, for when by raising the heat a complete fusion of the oxyd is produced, the colour turns to yellow. This change is ingeniously prevented by combining the oxyd previously with alumine, by mixing the sulphat of iron and alum together in solution, and precipitating both together by carbonat of potash, as mentioned under the article *Enamel*.

A great many preparations of iron for these purposes have been given, particularly the *saffron of mars*, the *ethiops*, and the red oxyd precipitated from any of the solutions, all of which will be mentioned under the article *Iron*. It does not appear however that there is any certain foundation for preferring one to the other, for even the perfect oxyd by nitric acid, and which is itself of a dark red-brown, when fully vitrified produces a yellow or brown according to the dose, as well as any of the sub-oxyds. Brogniart asserts that the presence of the oxyd of lead singularly disposes the perfect oxyd of iron to lose its red or rose colour, for which it is used in enamelling, when urged by strong fire, but when no lead is present the colour is fixed.

Of Copper. All the oxyds and carbonated oxyds of copper produce a fine green when thoroughly vitrified with any kind of glass or flux, and this colour is one of the easiest to produce in experiments in the small way. There does not seem to be much reason for preference of one preparation over the other. Those the most frequently employed are the carbonated oxyd produced by adding a carbonated alkali to the sulphat of copper, and also the *æs uftum* or copper oxydated and calcined simply by heat and access of air. This metal however may be made to give a carmine red (or mixed with iron

a full deep red) by adding to glass containing it a quantity of tartar when in complete fusion and working off almost immediately. The oxyd of copper must in this case be reduced nearly to the reguline state. A greater continuance of the heat restores the green colour. The oxyd of copper is also often mixed with manganese and iron in the composition of the full-bodied black glass. This oxyd when combined with thrice its weight of alumine runs in a strong heat into an opaque red enamel.

Of Lead. The oxyds of lead naturally give a yellow tinge to glass, but only considerably so when in very large quantity. Their use as a flux has been repeatedly mentioned, and they will readily vitrify most completely in a moderate heat without addition, or will unite with any other vitrifiable matters and most powerfully assist their vitrification. This oxyd is seldom used directly as a colour, on account of the enormous proportion required, which should be at least three-fourths of the glass to give a yellow of any intensity, and this would give a compound extremely soft and one that would powerfully corrode the crucibles.

Of Antimony. The perfect oxyd of this metal gives a full yellow to glass which is much used, both alone and in compound colours in which yellow is a necessary ingredient.

Of Manganese. The peculiar circumstances attending the use of this metallic oxyd in glass-making have already been mentioned. When not in contact with carbonaceous matter the proper colour given by this oxyd to glass is a purplish-red, rather muddy when in full body, but still very beautiful. It is almost always combined with nitre when thus employed. The colour is totally destroyed by all the arsenical salts as before mentioned, and therefore arsenic in any form should be avoided when manganese is used as a colouring matter. It also is the principal ingredient in most of the black glasses.

Of Cobalt. The colour given by the oxyd of this metal is a fine deep blue, which is unalterable in any fire, and succeeds with any flux. The colouring power is also very intense. Zaffre is usually employed for this purpose. Cobalt is also used for some of the finer blacks mixed with manganese and iron, and with the yellow of antimony and lead it composes a green.

Of Nickel. Though this oxyd is not actually used it may here be mentioned that the oxyd gives a violet-blue glass with fluxes of potash and to those glasses in which it largely enters, but not with soda or borax. Klaproth has fully

ascertained this in his analysis of the Chrysoprase,^c which, from its giving a blue to potash glass, was thought to contain cobalt, but this is not the case, the colouring matter being nickel. Thus 1 part of the rough chrysoprase, and 2 parts of carbonat of potash fused into a violet-blue glass; and 80 parts of silic, 60 of carbonat of potash, and 3 of oxyd of nickel from the chrysoprase, also gave a violet-blue glass. The same result was given by using an oxyd of nickel from a known ore of that metal. Equal parts of the chrysoprase and of carbonat of soda gave a tourmaline-brown glass nearly opaque. Equal parts of chrysoprase and calcined borax gave a brown transparent glass: and 60 parts of silic, as much borax, and 3 parts of oxyd of nickel, also gave a clear light brown glass. Silic, phosphoric acid, and oxyd of nickel in the same proportions gave a honey-yellow glass but not quite clear.

Of Tungsten. Though this is not used it may be mentioned that with fluxes of phosphoric acid it gives a blue glass, but not when borax or alkalies are used.

Of Chrome. This metal which is the natural colouring matter of the ruby and emerald, would be a most valuable ingredient for the artificial gems if it could be procured with tolerable ease. It has been found to give a fine red and also a most beautiful and exquisite green to glasses, but its great scarcity has prevented its frequent use. (See *Chrome*.)

Having thus generally described the colouring properties of the several metallic oxyds, some of the actual recipes for the different coloured glasses may be mentioned. These we shall chiefly give from M. Fontanieu, and from Neri and Kunckel, to which may be added the actual composition of a few of the beautiful antique coloured glasses, as found by the analysis of Klaproth.^d With regard to the recipes however, it may be added that there appears such enormous difference in the relative proportions of the metallic oxyds to the fluxes used, as either to give a suspicion of extreme inaccuracy or to shew that it must in most cases be determined by individual experience.

Of the Ruby red, Purple, Violet, &c. by Gold. Little can be added here to what has been said above under *Gold*. The particulars of the process have always been carefully kept secret by the successful artists, and from the frequent failures there can be no doubt that it is a very difficult process to manage. According to Kunckel and others who have succeeded, it appears that the colouring power of the *purple*

precipitate of Cassius, or the mixed oxyds of gold and tin, is so great that one part will give a full rich body of colour to from 600 to 1000 or more of glass. The glass of antimony too seems an important addition. This ruby glass comes out of the fire colourless, but assumes its beautiful hue as it cools. It has been thought that the colour is also further brought out by exposure to smoke.

Of other Reds, Purples, and Violets. Some of these are composed of a colourless glass basis, such as one of the five before mentioned, with manganese either alone or with the purple precipitate of gold, or more commonly with the oxyd of cobalt. The colour given by manganese being of a violet red, the cobalt will give it a more decided purple by adding its natural blue. It is impossible to pick out from the various recipes any other proportions than that the oxyd of manganese will colour very fully about 100 times its weight of glass when used alone, and when employed with cobalt, 200 parts of glass will be highly coloured with 1 of manganese, and (for a purple) about $\frac{1}{3}$ to $\frac{2}{3}$ of zaffre.

Neri gives the following receipt for a glass to imitate the garnet, namely, 2 oz. of rock crystal, 6 oz. of minium, 16 grains of manganese, and 2 grs. of zaffre. Kunckel gives for a violet red glass a common lead-glass basis with $\frac{1}{12}$ of manganese, mixed with nitre. Fontanieu gives for the imitation of the amethyst, 24 oz. of his glass, No. 5 (as already described), $\frac{1}{2}$ oz. of manganese, and 4 grains of purple precipitate of gold, together with $1\frac{1}{2}$ ounce of nitre. But the quantity of colouring matter here is so enormous that the vitreous basis should probably be 24 pounds instead of ounces.

A fine red has been mentioned to be procured from the oxyd of copper (with or without oxyd of iron) mixed with the due proportion of glass and with carbonaceous matter stirred in. For a full deep red the oxyd of iron should be three or four times as much as the copper, and in proportion as the latter predominates the colour approaches to carmine. The glass at first should appear when hot only of a faint greenish-yellow, and, when in full fusion, some tartar is stirred in, which instantly reddens the whole and causes it to swell prodigiously, after which it again subsides into a clear red glass, which should be worked off without delay. Probably charcoal would answer as well as tartar.

The antique red glass analyzed by Klaproth must probably have been made in the same way,

^c Essays, vol. 1.

^d Phil. Journ. vol. 8.

that is by carbonizing a glass containing the oxyds of iron and copper. The colour was a lively copper-red, perfectly opaque and bright at the point of fracture. The earthy and metallic parts of 400 grains, as given by analysis, were as follows:

Silex - - - -	142
Oxyd of lead - -	28
Oxyd of copper - -	15
Oxyd of iron - -	2
Alumine - - - -	5
Lime - - - -	3
	195

It is observable that this was opaque, whereas the former mentioned glass is transparent. Klaproth conjectures that this antique glass was made not by any intentional proportion or selection of ingredients, but from the scoræ of some copper ores.

Of Green Glasses. For these, which are intended to imitate the emerald when full-bodied, and the aqua-marine when light, there are many receipts.

Among others the following may be selected. Take 160 parts of any glass basis into which much lead enters, as the glass No. 1, 2, 3, or 5, mix it with 4 parts of the oxyd of copper made by simple calcination, and $\frac{1}{80}$ of a part of any oxyd of iron, and melt with a sufficient heat. In this as in all the other emerald colours a very small addition of iron seems highly useful to give somewhat of a richness of tint, and to take away the cold hue of the copper alone. For this reason too the rich yellow of the lead is of so much advantage.

Another is, 576 parts of the glass basis, 6 of the same oxyd of copper, and only $\frac{1}{44}$ of oxyd of iron. Another is, 200 parts of fine sand, 400 of minium, 8 of calcined verdigris, and 1 of oxyd of iron. The variation in these proportions is extreme.

Another method of composing the emerald-green is by a mixture of blue and yellow glass in due proportions. The yellow may be given by the oxyd of antimony, and the blue by cobalt. Fontanieu gives for this 120 parts of any of the glass bases, 1 of *mountain blue*, and $\frac{1}{12}$ of glass of antimony: or else 576 parts of the glass No. 2, 20 of glass of antimony, and 3 of oxyd of cobalt (not zaffre).

When the green has a sensible mixture of blue in the tint it forms a fine somewhat cold colour resembling the aqua-marine. This is produced in general by adding cobalt in some

form or other to the materials for the green glass. For this the following receipts are given by Neri, Kunckel, and Fontanieu. Melt 300 parts of any fine crystal glass made without manganese, add thereto at intervals 6 parts of calcined copper or any similar preparation, and $\frac{1}{4}$ of a part of zaffre, stir the glass well while mixing, and then let them fuse quietly for some hours. No reasons appear however why the whole materials should not be mixed at first as in the usual mode. Another is, 300 parts of fine soda glass with 6 of calcined brass, melted together, stirred twice at long intervals, the heat being continued a long time, and finally suffered to remain in quiet fusion for many hours before working. Another is, 256 parts of fine glass, and 150 of litharge or minium, first melted together and well mixed (or else any of the glass bases already mentioned that contain lead), to which is added 4 parts of calcined brass or of oxyd of copper made by calcination, and $\frac{1}{2}$ a part of zaffre. Another receipt for this colour is a mixture of yellow and blue, in such proportions that the blue shall prevail a little over the perfect green, the natural result of the mixture of blue and yellow. This is done by adding to 24 parts of the glass basis No. 1 or No. 3, $1\frac{1}{3}$ part of glass of antimony, and $\frac{1}{18}$ of a part of oxyd of cobalt.

According to Klaproth's analysis of a portion of an antique verdigris-green opaque glass, the colour was formerly, as now, given by copper and a small portion of iron, the same in kind as those that composed the red glass above mentioned, and probably also the oxyds were not artificially mixed but were used as contained in a natural ore. Two hundred grains of this green glass or paste yielded

	grains
Of Silex - - - -	130
Oxyd of copper - -	20
Oxyd of lead - -	15
Oxyd of iron - -	7
Lime - - - -	13
Alumine - - - -	11
	196

Of Blue Glasses. These glasses, which are intended to imitate the sapphire, are composed of a common basis and coloured with cobalt, but generally with the addition of a quantity of manganese, which by adding a violet tint gives a greater richness of body. When the manganese is in large proportion, the colour then is a rich violet blue or purple resembling the ame-

thyst. There appears no agreement in the different receipts as to the relative proportions of manganese, only that the latter should be in less quantity than the cobalt when used in the dilute form of zaffre. These mixtures appear to be materially improved by being twice melted and poured into water and powdered between the first and second fusion. Among the several receipts the following may be given, namely, to 100 parts of a fine glass, without lead, add 1 part of zaffre and $\frac{1}{16}$ of a part of manganese. Another is 240 parts of glass frit, made with soda and sand only, 192 of minium, 2 of zaffre and $\frac{1}{3}$ of manganese melted twice and treated as above. Or a very fine blue glass may be made simply by the glass No. 5, with a necessary dose of oxyd of cobalt or zaffre.

Though blue glasses cannot be now made without cobalt, it is certain that iron in some mode of combination gives this colour in great perfection. It appears to be the natural colouring matter of the sapphire, lapis lazuli, and some other blue minerals, and is frequently produced accidentally in the scorix of iron ores. The art of colouring pastes and enamels blue with iron was certainly known to the antients but is now entirely lost. This is proved by the analysis of some of the antient blue enamels, in which no metallic matter but iron, with a small proportion of copper, can be detected. Whether the copper assists in the effect cannot be told. Klaproth analyzed an opaque antient Roman enamel, the colour of which was sapphire blue verging towards that of smalt, and found the following ingredients.

	parts
Silex - - - - -	163
Oxyd of iron - - -	19
Oxyd of copper - - -	1
Alumine - - - - -	3
Lime - - - - -	0.5

186.5

Some of these plates of enamel were coloured equally throughout, others only to a certain depth on one surface, and the colour was given so uniformly that the plate had the appearance of two plates, one blue and the other colourless, adhering to each other.

Of yellow Glasses. The oxyds of lead, antimony, and silver are those which are used to give a yellow to imitate the varieties of the topaz, or the yellow diamond. M. Fontanieu gives the following proportions: 24 parts of the glass No. 1, or No. 3, and $\frac{1}{4}$ of a part of glass of antimony, or for the deeper coloured topaz, $\frac{1}{8}$.

For the imitation of the Brazilian Topaz he advises 192 parts of the glass No. 2, or No. 3, $8\frac{1}{2}$ parts of glass of antimony, and $\frac{1}{3}$ of a part of the purple precipitate of gold. An inferior yellow glass may be made by fusing simply 2 parts of fine sand or filex of any kind, with 7 parts of minium, but this is very soft. The delicate hue of the yellow diamond is imitated by adding to 576 parts of the glass No. 4, 25 parts of luna cornea, or ten parts of glass of antimony.

A colour varying in shade from brown to dingy smoke yellow, and thence to a fine transparent yellow, is given to common glass simply by adding to it when in soft fusion, any vegetable carbonaceous matter, part of which rises to the top and is burnt off, but a part also remains uniformly diffused through the glass, and gives it a fine yellow without impairing its transparency. No continuance of the fire will burn out this yellow colour altogether, after it has once lost its dingy smoked hue and acquired a clear yellow. Tartar has been commonly used for this purpose, but almost any vegetable inflammable substance not fluid, will probably do as well; the soft charcoal of the beech answers the same purpose. Manganese has been employed in the composition of this glass, but it appears to be of no use.^a Sometimes the carbonaceous matter is added to the glass frit when beginning to melt in the glass pots, at other times it is mixed with it before firing. A little nitre is found of use in clearing the colour and correcting the smoakiness, but too much of it will destroy the colour altogether. This glass swells much in the pot, when preparing, owing to the escape of part of the carbonaceous matter, especially when tartar is employed: but probably with quite dry and fresh burnt charcoal, previously heated strongly in close vessels for about an hour, no such effect would take place.

Of the Artificial Diamond. Though no art has ever invented any vitreous composition which can be mistaken for the real cut diamond, by an eye at all practised, (unless by particular artifices in the setting, which are easily detected) yet some artists can prepare a very fine brilliant hard glass paste, which possesses great beauty, and a very considerable water or play of light, which more nearly imitates the diamond than all the common artificial gems. It will be sufficient here to add that M. Fontanieu recommends his glass No. 1, for this purpose. These glasses require a considerable length of time of strong fusion before they are

^a Lewis Commerce of Arts, p. 628.

brought to the state of the greatest clearness and brilliance.

Of Opaque Glasses.

The materials which form the opaque glasses are a common vitreous basis, as for the coloured glasses, and either an excessive dose of colouring metallic oxyd which shall give such a depth and body of colour as to produce opacity, or a substance which of itself gives an opaque whiteness, to which any colour may be afterwards added if required. In general it is only the black glasses which are made opaque by mere quantity of the same colour which, in smaller proportion, would be transparent; and the white glasses are made with a glass rendered opaque by some addition which in any proportion impairs the transparency; and the blue, green, yellow, and other coloured opaque glasses have the white glass for a basis, and are coloured in the same way as the transparent glasses.

White Glass. The finest white glass is a vitreous base made opaque by the oxyd of tin, and is then called *Enamel*, (which see).

But a very good white may be made at less expence by substituting for the oxyd of tin a pretty large quantity of bone-ash or phosphat of lime in very fine powder. It appears to be owing chiefly to the extreme infusibility of this earthy salt that the opacity is produced, so that in fact the glass thus made is a common vitrescent compound holding in intimate mixture a quantity of unvitrescible earth.

Neri's receipts for white glass are the following: mix together 60 parts of white sand, 40 of potash, and 10 of finely powdered bone-ash, and melt for the usual time of glass-making. The result is a glass which when fully red-hot is transparent, but becomes milky and opaque as soon as it cools. It does not appear certain whether this change is chiefly owing to a deception of sight which does not allow the degree of opacity to be distinguished when red hot, or whether the glass really becomes opaque only when it cools, and then deposits the bone-ash by the effect of a kind of supersaturation by heat.

Another receipt is, 130 parts of sand or calcined flint, 70 of nitre, 12 of borax, 12 of tartar, 5 of arsenic, and 15 of bone-ash.

An imitation of the opal is made according to Fontanieu by mixing 576 parts of the glass No. 3, 10 of luna cornea, 2 of magnetic iron ore, and 26 of bone-ash.

Black Glass. It is not easy to make a very full-bodied, perfectly opaque, fine black glass. This is commonly made by manganese, and it has been found that one part of this oxyd

will give a full body of opaque black to about 20 of glass. A finer black used chiefly by the enamellers is made (as appears) by mixing together equal parts of manganese, zaffre, and scales of iron, and fusing one part of this mixed powder with 15 or twenty of any kind of glass.

For the other opaque coloured glasses no more need be added than that they may be made in the same way as the transparent coloured glasses, substituting the opaque white glass for the common vitreous base. These however are not much used in mass, or for any of the common useful or ornamental purposes to which the transparent glasses are applied. The opaque coloured enamels are composed on the same general principles, the base being the white enamel made with the oxyd of tin.

GLASS OF BORAX is borax calcined till it loses its water of crystallization and flows into a very thin limpid glass. A moderate red heat is sufficient for the purpose. This becomes slightly opaque by exposure to the air, in consequence of an incipient efflorescence.

GLASS-GALL, or *Sandiver*, is the scum of the glass-pots which arises during the vitrification of the frit. See **GLASS**.

GLASSES (*Metallic*), are the oxyds, or sometimes the sulphuretted oxyds of the different metals vitrified by heat. Those of lead and antimony are the most familiar to Chemists. (*See the respective metals.*)

GLAS SCHORL. See **THUMERSTEIN**.

GLAUBER'S SALT. See **SULPHAT OF SODA**.

GLAUBER'S SALT,^a native. *Naturliches Glaubersalz, Germ.*

Its colour is greyish or yellowish-white. It occurs generally efflorescent or incrusting, rarely stalactitical, and sometimes in minute acicular or middle-sized prismatic crystals. Internally the crystals are shining, with a vitreous lustre, but by a short exposure to the air they become dull and efflorescent. Its fracture when crystallized is conchoidal, when amorphous is earthy. It varies from transparent to opaque, according as it is more or less in a state of efflorescence. It is brittle and easily frangible, has a bitter saline taste, and is readily soluble in water. It gives a copious precipitate with barytic salts, but is not altered by carbonated potash. When fully saturated with water of crystallization it contains according to Bergman,

Sulphuric acid	27
Soda - - -	15
Water - - -	58
	100

^a Brochant. Jameson.

The native Glauber's salt however, especially when efflorescent, contains besides pure sulphat of soda, some oxyd of iron, accidental earthy impurities, and more or less of muriat and carbonat of soda. It is met with in old salt-mines, on the borders of salt-lakes in Hungary, Tartary, and Egypt, and on the surface of certain peat mosses especially in the north of France. It is contained in solution in the Natron-lakes of Egypt, and the mineral springs of Carlsbad.^b

GLIMMER. See MICA.

GLIMMERSCHIEFER. See MICACEOUS SCHISTUS.

GLUE. See GELATIN.

GLUTEN, (*Animal.*) See FIBRIN, and BLOOD.

GLUTEN, *vegetable*. A substance very closely resembling animal gluten in all the essential chemical properties, is found in several vegetables, and hence it has received the name of vegetable gluten.

Wheat flour was first found by Beccari to contain it in considerable quantity, and it is from this source that it is usually obtained for experiment by the following simple and easy process.

Moisten any quantity of wheat flour with a little water, and knead it with the hand into a tough ductile paste, then let a very slender stream of water keep dropping on the paste while it is incessantly worked about with the hands, and the water will run off white and turbid, owing to the fecula or starch which it carries off. The paste in the mean time gradually becomes more of a grey and almost semitransparent appearance, and when the water runs off quite clear, nothing is left in the hands but pure gluten. No other precaution is required in this preparation but that of not drenching the flour at first with water, but only using a very small quantity with much kneading, that the gluten may not be carried off along with the starch. Good wheat flour will yield in this way about a fourth of its weight of gluten, and no other flour but that of wheat will yield it except in a very small proportion, and hence probably the peculiar property of wheat flour to make bread without any other addition than a ferment. See the article BREAD.

Gluten thus prepared is soft, extremely tenacious and elastic, so as to bear being extended considerably without pulling in pieces, and returning to its former dimensions. It is also considerably adhesive, readily sticking to the fingers. Its colour is a dirty grey, and it has a

faint and peculiar smell. It readily dries into a brittle semitransparent substance, which looks not unlike glue, and in drying, it strongly adheres to the substance on which it rests: so that advantage is taken of this property to cement together broken pieces of china and other rough surfaces.

Gluten is absolutely insoluble in water, though it must owe its adhesiveness and ductility to the water which it absorbs when the flour is first wetted. Boiled with water it only becomes denser, and loses part of its adhesiveness. All the acids, vegetable as well as mineral, the latter being diluted, dissolve it without difficulty, forming a clear solution, from which it is again separated by alkalies. Strong sulphuric acid blackens and carbonizes it, and disengages from it an inflammable gas, and converts it partly to acetous acid, partly to ammonia. Concentrated nitric acid when cold disengages azotic gas from it, when hot it converts it chiefly into malic and oxalic acids with evolution of much nitrous gas and ammonia.^a

The alkalies also dissolve gluten with ease.

When gradually heated without addition, it dries thoroughly, then shrinks and coils up like most other of the soft animal substances, then melts and takes fire, burning with the fetid odour of animal matter.

In close vessels it yields some ammoniacal water, and a very brown fetid thick oil in abundance, together with crystallized carbonat of ammonia and carburetted hydrogen.

In short, it exhibits to chemical analysis all the properties of animal matter.

Gluten, when dry and kept so, remains unaltered for any length of time, but if kept constantly moist in the state in which it was first procured, it slowly alters, loses much of its tenacity, becomes fetid and covered with a thick white down, and falls into putrefaction. This process however is slow, and at the same time a sour smell is perceivable, and an acid is generated which probably corrects and retards the proper putrefaction. In this circumstance it is that it chiefly differs from animal gluten.

M. Cadet^a has found that gluten after being kept for many days moist and mouldy is partially soluble in alcohol. Some of this gluten was rubbed up with alcohol and passed to the state of a thick turbid syrup; on adding more of the spirit much of the gluten separated in its original form, but a part remained in perfect solution. This latter being diluted with water immediately became milky, and let fall a copious white pre-

^b Klapr. analy. Ess. I. p. 296. II p. 60.

^a An. Chim. tom. 41.

precipitate which appeared like a fecula, but was gluten in intimate division. Another part of the alcoholic solution being gently evaporated left behind a dry, brittle, yellowish, glossy gluten, appearing like a varnish, and which the author of the experiment proposes to be used for this purpose, either by itself, or as a vehicle for colours of different kinds.

Gluten is contained in small quantity in several vegetable juices and other parts, and may be separated from them with care: though in none is it so abundant as in wheat flour. Bird-lime, a singular substance extracted from the bark of the holly and also from the mistletoe, is supposed to be chiefly gluten, and the green *FECULA* of plants also appears to be composed very largely of this substance, as mentioned under that article.

GLYCINE. *Glucine.* Fr. The discovery of this earth is due to Vauquelin,* who first found it in the beryl and afterwards in the emerald: the existence of a new earth in these minerals has since been confirmed by the researches of Klaproth^b, so that the existence of glycine as a peculiar earth may be considered as established very satisfactorily. Its name is derived from the greek *γλυκός* (sweet) on account of the remarkably saccharine taste by which its salts are distinguished. This however although a striking character at the time when the earth was first discovered has since ceased to be a specific distinction as it is possessed both by glycine and the still more recently discovered earth called Yttria, (see p. 455.)

In order to procure glycine in a perfectly pure state, take any quantity of beryl or emerald, and having reduced it to very fine powder, mix it with about three times its weight of caustic potash in a liquid form, and digest it to dryness in a silver crucible, after which let it be moderately ignited for about half an hour: the resulting mass will be found to be entirely soluble in a slight excess of muriatic acid, and the solution after being evaporated to dryness and then diffused in water, will deposit nearly the whole of the flux. The muriatic solution is now to be supersaturated with caustic potash or soda and boiled, by which the oxyd of iron and of chrome, if any is present, will be separated. The clear liquor being again supersaturated with muriatic acid and afterwards mixed at a boiling temperature with carbonat of soda, deposits the whole of its earthy contents in the form of a white soft precipitate: this when well washed in water, is to be dissolved in sulphuric acid,

and the solution being transferred to a ground stoppered bottle is to be considerably supersaturated with carbonat of ammonia: both the alumine and glycine will be at first precipitated, but this last, by the assistance of occasional agitation will be redissolved in the course of a few hours. The clear liquor being poured off, the earthy residue is to be again dissolved in sulphuric acid, and sulphat of potash being added, a copious deposit of crystals of alum will take place: the mother liquor and washings of the crystals being again treated with a large excess of carbonated ammonia, the remaining portions of glycine will be extracted, and the two ammoniacal solutions are to be added together. This fluid when boiled in a retort will deposit the whole of the glycine in the state of a white powder, and combined with carbonic acid: after being washed and dried it must be ignited, by which it will lose carbonic acid and moisture to the amount of about half its weight, and the residue is pure glycine.

Glycine is a white powder, soft and somewhat unctuous to the touch, adheres strongly to the tongue, is insipid and inodorous. It produces no change on vegetable colours, and therefore does not belong to the class of alkaline earths. It does not contract in its dimensions by heat, nor is it fusible: but with the assistance of borax it runs into a clear transparent glass. Its sp. gr. is 2.96. It is not soluble in water, but when moistened with this fluid it forms a somewhat ductile paste. It combines with sulphuretted hydrogen through the medium of water. It is soluble in the liquid fixed alkalies, resembling in this respect alumine. It is insoluble in ammonia, but dissolves readily in carbonated ammonia as yttria does, except that this latter requires for its solution five times as much of this menstruum as glycine does.

It unites with the acids forming saline compounds, all the soluble ones of which have a remarkably sweet subastringent taste.

Carbonat of Glycine may be prepared either by precipitating sulphat of glycine by either of the carbonated fixed alkalies, or simply by heating the solution of glycine in carbonated ammonia: a white impalpable powder falls down, which is carbonat of glycine.

This salt according to Klaproth consists of

Glycine	-	-	-	-	53
Carbonic acid and water					47
					100

* An. de Chim. xxvi. p. 170.

^b Analyt. Ess. II. p. 172-176.

It is decomposable by a low red heat, the acid and moisture being driven off: it is also decomposable with effervescence by the other acids.

Phosphat of Glycine is obtained by adding phosphat of soda, to sulphat, nitrat, or muriat of glycine: a white pulverulent precipitate falls down, which is the salt in question. When perfectly neutralized it is uncrystallizable, insoluble in water, and insipid: at a high heat it melts into a transparent glass: when the acid is in excess it is soluble in water. It is decomposable by the alkaline carbonat and alkaline earths, except carbonat of magnesia, and by the sulphat, nitrat, and muriat of alumine.

Sulphat of Glycine is procured by adding either pure or carbonated glycine to sulphuric acid till this last is perfectly saturated: by spontaneous crystallization, sulphat of glycine is deposited in octohedrons composed of two oblique four-sided pyramids joined base to base, with the edges and solid angles truncated. The taste of this salt is very sweet, and somewhat astringent: it is readily soluble in water, and tincture of galls added to the solution occasions a yellowish white precipitate. The solid salt when heated dissolves in its water of crystallization, and afterwards becomes pulverulent: at a red heat the acid is entirely driven off, the pure earth being left behind.

If a little sulphat of potash is added to a solution of sulphated glycine, and the liquor is slowly evaporated, a quantity of small crystalline grains are deposited which are readily soluble in seven or eight times their weight of cold water. If carbonated glycine is digested in a solution of common alum, the glycine is taken up and the alumine entirely precipitated.

Nitrat of Glycine is prepared in the same manner as the preceding salt, by substituting the nitric for the sulphuric acid. Its taste is sweet and astringent, it is strongly deliquescent, and when evaporated assumes the consistence of honey, but does not crystallize: like the preceding salts it is decomposable by a red heat the acid being evaporated. With tincture of galls it gives a yellowish brown precipitate.

Muriat of Glycine both in the mode of its preparation and in its general characters bears a close resemblance to the preceding, it is however capable of being crystallized, which is not the case with nitrat of glycine.

Neither the pure earth nor any of its salts have been applied to any use.

GNEISS.^a Gneiss is essentially an aggregate of quartz, felspar and mica: of these substances

the latter is in the form of extremely thin plates, all of which are arranged in the same direction and parallel to the general inclination of the stratum. In its composition, gneiss is the same as granite, but differs in the arrangement of its parts, especially of the mica, which in granite is dispersed throughout its substance in every direction; gneiss has a slaty texture and splits readily in the direction of the mica, hence from its longitudinal fracture it would be supposed to consist almost wholly of this substance, while from its cross fracture it seems made up of quartz and felspar interrupted by very narrow lines of mica.

There are three varieties of gneiss. In the first each ingredient forms a distinct stratum irregularly alternating with the others and representing on its cross fracture parallel bands of quartz, felspar, and mica, either even or undulating. This variety forms the connecting link between granite and common gneiss, the undulatingly banded, passing immediately into the latter, and the even banded, which may without impropriety be named banded granite, *granite veiné of Saussure*, into the former. The second variety is common gneiss: in this the ingredients are more mingled than in the preceding, and its fracture is coarsely slaty. When the component parts are still more intimately mixed, the mass belongs to the third variety or foliated gneiss: the fracture of this is fine slaty passing into foliated, and the mica seems to prevail, if not in quantity at least in efficacy over the quartz and felspar, the characters of which are obscured by those of the mica: when the mica is very predominant, the rock passes into micaceous schistus.

The quartz in gneiss is generally of a whitish or smoky grey colour, and it is either opaque or slightly transparent. The felspar in those specimens that pass into granite is mostly flesh-red, in the others it is greyish or yellowish white. The mica is silvery white or tombac brown verging upon black. It sometimes though rarely happens that the felspar is in a state of decomposition approaching to porcelain clay, whence some authors have mentioned indurated clay as a component part of gneiss.

Among the substances accidentally inclosed in gneiss may be reckoned garnet, which very frequently, and schorl which very rarely occurs, also fragments of granite, hornblende, and occasionally steatite. Gneiss is one of the primitive rocks, and in its formation is considered as immediately posterior to granite, as it is usually

^a Lenz. Brochant.

found to rest upon this: it is distinctly stratified, and between the strata are sometimes interposed beds of granular limestone, hornblende slate, common actynolite, quartz, and rarely porphyry. This rock is remarkably rich in metallic ores both in strata and veins: it contains gold, native silver, red and white silver ore, tin stone, galena, martial, arsenical, and copper pyrites, blende, arsenical cobalt, &c. accompanied by brown spar, heavy spar, fluor spar, calcareous spar, quartz, clay porphyry, wacke, hornstone and jasper. Most of the Saxon and Bohemian mines are in gneiss, as also are the silver mines of Kongsberg in Norway.

Gneiss although a common rock, is by no means of so frequent occurrence as granite.

GOLD. *Gold*, Germ. *Aurum*, Lat. *Or*, Fr. *Sol*, Alchem.

Gold is a metallic substance of a pure yellow colour, remarkably ductile and malleable, of great specific gravity, and nearly as soft as tin. In fusibility it ranks between silver and copper; it is not oxydable by fusion in atmospheric air; nor is it acted on by any of the acids except the oxymuriatic and nitro-muriatic (aqua-regia.)

§ 1. Ores of Gold.^a

Gold is found only in one state, namely, the reguline, but is hardly ever pure, being alloyed more or less by silver, copper, tellurium, and a few other metals. When alloyed with silver or copper, or with both, it preserves its ductility, and is reckoned as native gold; when combined with tellurium it entirely loses its discriminative external characters, and in this state is generally classed among the ores of tellurium. For the convenience however of the reader, we shall describe this latter substance both here and when we come to treat of tellurium, trusting that a little repetition will be excused on this account.

1 Sp. Native Gold. *Gediegen Gold*. Wern. *Or Natif*. Broch. and Haüy.

Its colour when pure or nearly so, is a bright, somewhat orange yellow; in proportion as it is alloyed with silver it inclines to a pale brass yellow; when combined as is supposed with platina, it passes from brass-yellow to steel-grey. It occurs in detached lumps and grains, disseminated, superficial, reticulated, dendritical, capillary, cellular and scaly, as a snuff-coloured powder, and sometimes, though rarely, crystallized in small cubes, regular octohedrons and rhomboidal dodecahedrons. The crystals are for the most part minute and very irregular. The surface of the crystals is smooth and brilliant; of the

other varieties the lustre is faintly shining and glimmering; when cut with a knife it displays a bright and perfectly metallic lustre. Its fracture is hackly. It is very soft, perfectly ductile and flexible, but not elastic. Its specific gravity varies according to its purity from about 17. to 19.

Before the blow-pipe it runs into a globule without emitting any vapour.

Native gold is rather a rare mineral, and is by no means the principal source of this valuable metal. It occurs in veins or dispersed through the substance of primitive mountains, especially argillaceous schistus, and clay porphyry, and is accompanied by quartz, felspar, calcareous and heavy spars, pyrites, red and vitreous silver ore, galena, &c. The richest mines of native gold are found in Brazil, Peru, and Mexico; some of the African, Sumatran, and Japanese gold, is also procured from a similar source; the mine of Beresof in the Uralian mountains, and some of the Hungarian and Transylvanian mines likewise yield native gold, though in small quantities.

But by far the largest proportion of native gold is found accidentally dispersed through certain alluvial strata. That this is not its natural situation is manifest from its occurring here only in rounded and flattened masses, from microscopical spangles to pieces three or four pounds in weight, all of which exhibit decidedly the effects of friction. It is from the sands of certain rivers that this stream gold as it may be called, has been chiefly procured; and it was naturally thought that its original bed was at the mountainous sources of these streams, whence it was detached by the force of the torrents, and deposited in the lower and quieter part of the river. In some instances this is no doubt the case, but in most others the transportation of the gold appears to have taken place at a period anterior to the formation of our present rivers. Where gold is found in the bed of an actual torrent at no great distance from its source and in a mountainous country; where too the gold is confined within the present or probable former boundaries of the stream (as is particularly the case with that recently found near Cronebane in the County of Wicklow in Ireland) it may be considered as indicating the presence of gold, either dispersed or in a regular mine in the adjoining rocks. But on the other hand, when gold is found in the bed of a river at a considerable distance from its source; if the surrounding country is plain

^a Haüy, Brochant, Jameson.

or nearly so; if the auriferous sand forms a stratum extending to a considerable distance beyond the river; then it is probable that the river has merely cut through a previous alluvial stratum holding gold, and that to endeavour to find the mine whence this metal originated by searching the rocks towards the source of the stream, is mere loss of time.

A considerable portion of the stream gold seems to have been contained in auriferous pyrites, for almost all the sands from which this metal is extracted are highly ferruginous, and of a deep blackish-brown colour: the gold itself is mostly of a pale yellow, and is considerably alloyed with silver. The Peruvian, Mexican, and Brazilian rivers, are many of them extremely rich in gold, as are likewise several of the streams on the Western coast of Africa: in Europe, the Danube, the Rhine and the Rhone, afford small quantities of this metal, and from several other of the lesser rivers it has been extracted rather for curiosity than profit: the streams of Hungary and Transylvania, under the patient management of the Zigeuners or Gipseys, yield a greater quantity of gold than the rest of the European rivers, yet hardly sufficient to afford a very scanty maintenance to the labourers.^b Of the alluvial strata yielding gold, none has ever been found comparable in richness to the plain of Cineguilla in the province of Sonora, on the Eastern shore of the Californian gulf: this plain is about fourteen leagues in extent, and contains large lumps of gold irregularly dispersed through it at the depth of about 14 inches.

Sp. 2. Graphic Gold. *Schrifterz.* Wern. *Silvane graphique.* Broch. *Aurum graphicum.* *White Gold Ore of Offenbanya*, of the older mineralogists.

Its colour is tin-white with a shade of brassy-yellow: it occurs crystallized in small flattened prisms with four or six sides, and terminated by tetrahedral pyramids; the crystals are disposed in rows, and either parallel or at right angles to each other, giving the whole a sort of resemblance to writing (whence the name of this mineral). The crystals are smooth, and exhibit a bright metallic lustre: the fracture is fine-grained uneven. It is soft, brittle, may easily be cut with a knife. Sp. gr. 5.7.

When exposed to the blow-pipe it burns with a green flame, and a copious somewhat acrid vapour, leaving behind a malleable metallic globule. According to the analysis of Klaproth, it consists of

Tellurium	-	60
Gold	-	30
Silver	-	10

100

It has hitherto been found only at Offenbanya in Transylvania, in thin layers, upon grey quartz, in clay porphyry, and is accompanied by iron-pyrites, grey-copper, blende, and occasionally native gold.

Sp. 3. White Gold Ore. *Weiss Silvanerz.* Wern. *Silvane blanc.* Broch. Yellow Gold Ore of Nagy-ag.

Its colour is silver-white passing into brassy-yellow: it occurs disseminated, and in small imbedded prismatic crystals. Externally it has a bright shining metallic lustre. Its longitudinal fracture is foliated, the cross fracture is small-grained uneven. It is soft and somewhat ductile. Sp. gr. 10.6.

It consists according to Klaproth of

Tellurium	-	44.75
Gold	-	26.75
Lead	-	19.5
Silver	-	8.5
Sulphur	-	0.5

100.00

It has hitherto been found only at Nagy-ag in Transylvania, where it occurs in a gangue of quartz and brown spar, accompanied by blende, grey-copper, and copper-pyrites.

Sp. 4. Black Gold Ore. *Nagyagercz.* Wern. *Silvane lamelleux.* Broch.

Its colour varies from lead-grey to iron-black: it is seldom found in mass, being generally disseminated in the form of small scales, or long hexagonal plates, either single or accumulated on each other. It has a moderately shining metallic lustre. Its fracture is curved-foliated: it stains the fingers a little, is somewhat flexible, and very soft. Sp. gr. 8.9.

Before the blowpipe it readily enters into fusion, and the tellurium and sulphur are volatilized, leaving behind a metallic malleable globule surrounded by yellowish scorizæ.

It consists according to Klaproth of

Tellurium	-	32.2
Lead	-	54.
Gold	-	9.
Silver	-	0.5
Copper	-	1.3
Sulphur	-	3.

100.0

^b Born, Voyage Mineral.

It has been found as yet only at Nagy-ag in Transylvania, in a gangue of red manganese, brown spar, and quartz, accompanied by galena, iron pyrites, blende, plumose antimony and grey copper ore.

Sp. 5. Auriferous Pyrites.

The bronze-yellow IRON PYRITES in mass or in striated cubes, and the hepatic pyrites when occurring in veins in primitive mountains, are sometimes found to contain a sufficient quantity of pure gold, or of gold alloyed with silver, to be well worth the trouble of extracting by methods that will be described hereafter. It was formerly supposed that the gold as well as the iron in this ore, was mineralized by the sulphur; the experiments of Bergman however pretty clearly shew that this is a mistake, and that the gold in small scales is merely interposed between the laminæ of the pyrites. A considerable proportion of the American gold, and by far the largest portion of the Hungarian gold, is obtained from this ore. The produce of the Hungarian pyrites is very various, sometimes not exceeding a few grains of gold in the quintal of ore, but in the celebrated mine named Maria of Loretto, near Zalathna, in Transylvania, is a vein of auriferous pyrites, that occasionally yields as much as 450 oz. of gold in the quintal.^c

Sp. 6. Auriferous Galena.

The native Sulphuret of LEAD, commonly called galena, almost always contains a little silver, which not unfrequently is sufficiently abundant to be worth the trouble of extracting.

The galena of Hungary occasionally holds not only silver but gold, and is accordingly worked as one of the ores of this precious metal: the galena of Boicza yields an ounce and a half in the quintal of an alloy, of which 31 parts are silver and 1 of gold.^d

§ 2. Analysis of Gold Ores.

The analysis of gold-ores is very simple, the chief difficulty arising from the minute proportion of this metal contained in the greater part even of those ores which are reckoned very rich.

Native gold contains in variable but generally small proportions either silver or copper, and sometimes both; and its gangue is often quartz of extreme hardness. When this happens to be the case the following is generally the best mode of proceeding. After the ore has been reduced to fine powder let it be mixed with five or six times its weight of carbonated soda, or still better with 4 parts of carbonated soda and

1 of glass of borax, and melted in an earthen crucible: the mass when fused is to be poured out on a stone slab, and the small portion remaining in the crucible may be readily detached by a little diluted muriatic acid. The whole mass coarsely pulverized is to be put into a flask with this muriatic solution, and strong muriatic acid being added a gentle warmth is to be applied; the digestion must be continued, a little nitrous acid being added from time to time, till the action of the menstruum entirely ceases and the undissolved residue is of a pure white colour: the liquor is then to be poured off, the residue is to be well washed, and the washings added to the liquor.

a. The insoluble residue being dried is to be exposed to the sun, and will acquire a purplish tint if it contains any muriat of silver. Upon this indication it is to be mixed with thrice its weight of pearlash and fused in an earthen crucible for about five minutes; the silver will be reduced into metallic globules, and may be obtained pure by digestion in muriatic acid, which will take up the earth and alkali but will not act on the silver.

b. The nitro-muriatic solution being carefully neutralized with either of the fixed alkalies, a solution of green sulphat of iron is to be added as long as any precipitation takes place; this precipitate is gold, which being carefully collected is to be fused in a small crucible with just a sufficient quantity of nitre to cover it.

c. The residual liquor being decomposed by a carbonated alkali, the precipitate after being well washed is to be digested in liquid ammonia to take up the copper, which being done, the ammoniacal solution is to be slightly supersaturated with muriatic acid, and the addition of a stick of zinc will presently throw down the copper in the reguline state.

The second, third, and fourth species of gold ore containing a large proportion of tellurium are to be analysed in the following method.^e

a. The ore being finely pulverized and separated as accurately as possible from the lighter stony particles by washing, is to be digested with muriatic acid, to which must be added by degrees successive portions of nitric acid, till the black colour of the ore has entirely disappeared. The first solution being poured off, a fresh quantity of muriatic acid may be employed in order to render it certain that every thing soluble has been taken up. This being poured off and the residue welledulcorated with boiling water, all the three fluids are to be mixed together.

* Born, Voyage Mineral, p. 193.

* Ibid p. 217.

* Klapr. Analyt. Ess. II. p. 1.

b. The insoluble residue consists of quartz, and may also contain sulphur and muriated silver. The sulphur will be found collected into a mass by itself, which being dried, weighed, and afterwards ignited and again weighed, the difference of weight will indicate the quantity of sulphur; what remains after ignition is to be treated with nitro-muriatic acid, the soluble portion added to the former solution, and the insoluble part added to the other residue. The silver is collected by mixing four parts of pearl ash and one of glass of borax with the residue and fusing the whole, and afterwards separating the globules of silver by means of muriatic acid, as already mentioned.

c. The nitro-muriatic solution (a) upon the addition of the edulcorating water will let fall a white precipitate, but by subsequent heating and evaporation it will be redissolved, and instead of it, if any lead is present, acicular crystals will be deposited: the evaporation must be persevered in till these crystals cease to be produced: being then collected, carefully rinsed in a little muriatic acid and afterwards highly dried, they will be found to be pure muriat of lead.

d. The solution thus freed from the lead is to be diluted a little with water and then to be largely mixed with spirit of wine as long as any precipitate falls down; a gentle warmth will complete the separation, and the precipitate edulcorated with alcohol is to be redissolved in muriatic acid, from which it may be separated in the state of oxyd of tellurium by accurately saturating the liquor with caustic soda, or in the metallic state in the form of black flocks by means of zinc.

e. The remaining fluid is to be freed from its alcohol by evaporation or distillation, the concentrated solution is to be moderately diluted with water, and a solution of nitrat of mercury made in the cold is to be dropped in till the last portions of the precipitate are white: the precipitate, which is of a brown colour, is to be collected, washed, and fused with nitre, and yields a button of pure gold.

f. The liquor is now to be saturated with carbonated soda at a boiling temperature as long as any precipitate is thrown down: this being redissolved in warm muriatic acid, and again supersaturated with carbonat of ammonia, affords a precipitate containing iron and manganese.

g. The ammoniacal solution being slightly supersaturated with muriatic acid will deposit all its copper in the metallic state by the action of a piece of zinc.

It is not known whether gold ever exists

native in a state of proper combination with platina, nor is there any extant analysis of those ores in which platina is simply mixed with grains of gold. The method of proceeding however in such cases is sufficiently obvious by recollecting that though both the metals are soluble in aqua regia, yet gold alone is precipitable from this menstruum by the addition of sulphat of iron.

Auriferous pyrites is analysed by digesting the pulverized ore in muriatic acid with the occasional addition of a little nitric acid till every thing soluble is taken up; the residue being washed and dried is to be weighed and then exposed to a heat just sufficient to burn off the sulphur, the amount of which is indicated by the loss of weight. The residue is again to be digested in nitro-muriatic acid, and this solution is to be added to the first. The earthy residue containing the silver in the state of muriat is then to be fused with an equal weight of glass of borax and thrice as much pearl ash, the silver will be reduced and may be separated from the alkali and earth by very dilute muriatic acid. The nitro-muriatic solution is to be neutralized by fixed alkali and then treated with nitrat of mercury prepared in the cold, by which the gold will be thrown down in the state of a brown powder, and may be brought to the reguline appearance by fusion with nitre. The oxyd of iron remains in solution and may be obtained in the state of magnetic oxyd in the usual way.

Auriferous galena is to be treated nearly in the same manner as the preceding. By the action of nitro-muriatic acid the gold and lead, as well as the iron and antimony, if any are present, are taken up, leaving behind the earthy matrix, the sulphur and silver, which are separated as already mentioned in the former paragraph. The lead is deposited by gradual evaporation of the nitro-muriatic solution as crystallized muriat of lead, and the gold is procured from the solution again diluted with water, by means of nitrat of mercury.

Where a mineral is examined merely for the gold and silver which it contains, it is a usual practice to pulverize it very finely and digest it first in pure moderately strong nitric acid, and then in nitro-muriatic acid. In the first solution is contained the silver, in the second the gold. This however is a very inaccurate way of proceeding, especially for the silver, because whenever this does not greatly exceed the gold it will be more or less covered by it from the action of the nitric acid, and on the subsequent

digestion with nitro-muriatic acid will be converted into muriat of silver and thus rendered insoluble.

There are several ways mentioned by authors of analysing in the dry way, or rather of assaying ores of gold: none of them however are equal in accuracy to the modes of analysis by liquid menstrua which we have already mentioned, and are in fact only a more careful performance upon small quantities of materials of those processes which we are about to describe in the large way in the third and fourth sections.

§ 3. *Reduction of Ores.*

The richest gold mines concerning the working of which we have any very particular description are those of Hungary: the method of proceeding therefore in these establishments shall be first mentioned.^f The high commercial value of gold compared with that of any other metal depends in a considerable degree on its rarity, hence even the most profitable veins of gold are of trifling magnitude, and will pay very well to the miner though mixed very intimately with so large a proportion of stony gangue and other impurities as would render it impossible to work with advantage any other metal similarly circumstanced.

In the Hungarian mines the attention of the miner is not confined to the strings of ore, but the whole contents of the vein are usually extracted. It is raised for the most part in large masses to the surface, and is then distributed to the workmen, who break it first with large hammers and afterwards with smaller ones, till it is reduced to pieces of the size of a walnut or less. During this process each piece is attentively examined and arranged according to its value: the native gold even to the smallest visible grain is separated as accurately as possible from the quartz in which it is chiefly imbedded, and put by itself; the auriferous galena and pyrites are also thrown into separate heaps. The small splinters detached during this process, as well as the sand and mud of the mine are also collected, washed and sifted, and arranged according to their fineness and apparent richness. The portion rejected in this first examination is afterwards re-examined by boys, whose time is of little value, and who pick out nearly the whole of what has been overlooked by the men, and sort in it the manner just mentioned.

The native gold with its adhering matrix is again broken by hand into still smaller pieces, by which an additional quantity of impurities and stony matter is got rid of: it is then put into a

kind of wooden box floored with cast iron plates, and reduced to a fine powder by the action of two or more heavy spars of oak, shod with iron and worked alternately in the manner of a common stamping mill. This powder, or flour as it is called, being now removed into a convenient vessel like a large basin, is mixed with a sufficient quantity of salt and water to render it damp, after which a workman takes a thin porous leather bag, puts a quantity of mercury into it, and by a continued regular pressure forces the mercury in minute drops like dew through the leather: in this minutely divided state it falls upon the pulverized ore, and is immediately kneaded up with it till the requisite quantity (depending in great measure on the proportion of gold) has been added. This part of the process being completed, the mixture is rubbed together by means of a wooden pestle for some time to expedite the incorporation of the mercury and gold, and is afterwards heated in a proper vessel to about the temperature of boiling water for three or four days: finally, the mixture is washed very carefully by small parcels at a time, the earthy particles are carried off by the water, and there remains behind only the mercury combined with the gold into an amalgam. Part of the mercury is then separated by pressure in a leathern bag, and the rest is driven off by distillation, leaving behind only the gold and the silver with which it may happen to be alloyed. (For a fuller account of this process see SILVER.)

Such is the simple method by which the native gold of the ore is extracted; a much more complicated process however is required to separate that portion of the metal which is dispersed invisibly in the pyrites, ochre, galena, and other metallic substances, as well as the stony parts of the gangue. These in the sorting already described, are separated not only according to their apparent richness, but, what is of more importance, are also arranged according to their hardness. This being completed they are transferred to the stamping mill.

The principal parts of a stamping mill are the following: 1. The coffers or cisterns, usually two in number, in which the ore is pulverized, and through which a stream of water that may be increased or diminished at pleasure, continually passes. 2. The stampers or vertical beams shod with iron. 3. The axle, fixed horizontally, and working at one end in a pivot and rivetted at the other into the center of a large water wheel. Hence the mode of its

^f Delius, sur l'art des Mines. vol. II. Born, &c.

action is evident: a stream of water falling upon the wheel turns it round, and at the same time the axle to which it is attached: the cogs fastened upon the axle raise alternately the stampers to a given height, and then let them fall upon the ore that is placed in the coffer, which in proportion as it is sufficiently comminuted, is carried by the water that is continually flowing through, out at the sides of the coffer, into the labyrinths where the stony and metallic contents of the ore are deposited nearer to or further from the discharging aperture, according to their respective specific gravity.

The coffer is a rectangular hole sunk below the level of the ground, and both floored and lined with strong double oak planking: it is about four feet deep, five in length, and two feet or less in width. The stampers are five in number, and are strong oaken beams terminated with iron, and weighing about 200 pounds each; they are placed side by side, about two inches and a half distant from each other. When any ore is to be pounded, the first thing is to cover the bottom of the coffer with a close-set flooring or pavement, composed of large pieces of the hardest and poorest part of the vein, such a floor being found by experience to be much better on many accounts than an iron one. The thickness of this floor is inversely according to the hardness of the ore to be pounded; it being manifest that the higher this is the smaller will be the space through which the stampers have to fall, and therefore the less will be their momentum: care must however at all times be taken that the part of the floor immediately beneath the middle stamper, is about two inches lower than that below the stamper on each side of the middle one, and that this again is about an inch lower than that beneath the two outermost stampers. The coffer being thus prepared, the stampers are set in motion by the water wheel, a small stream is allowed to flow into the coffer, and the ore is thrown in just below the middle stamper, by a careful workman, or supplied in the proper quantity by a hopper: the ore being comminuted by this stamper, is gradually delivered to the next on each side, where it is still further pulverized, and from which it is passed on to the two outermost stampers, by which it is at length reduced to grains of such fineness, as to be for a time suspended in the water, and carried by it through one or other of the apertures which are at each end of the coffer.

Much care is required, especially in stamping the ores of gold and silver, in the first place

that no pieces be subjected to the process that can economically be separated by hand from the gangue, for even when it is the most skilfully conducted a very notable proportion will be lost; and secondly, that the ore be pounded either fine or coarse, or be subjected to greater or less force according as circumstances may require. If the ore is principally native gold dispersed in very minute particles through quartz or hornstone, it will be impossible to separate the whole or nearly the whole of the metal, except it is reduced to exceedingly fine powder, and this may be safely done both because the difference in specific gravity between the two ingredients of the ore is very great, and also because the quartz if reduced to particles ever so minute, does not at all clot and adhere to the gold. In this case therefore the floor of the coffer may be set as low as possible, to give the stampers their greatest momentum, and only a very small stream of water may be let in, that the current passing out of the coffer may carry with it only the smallest particles. It often however happens that the gold is disseminated in a very ochery and highly indurated clay, or in calcareous spar, and in this case there is only a choice of difficulties: if the ore is not extremely comminuted much of the metal will be kept in the earthy matrix, but if on the other hand the stamping is continued too long, the whole will be reduced to a fluid mud, which will prevent the thin laminae of gold from subsiding; and long practice and accurate judgment are required to manage the process so that the greatest quantity of gold shall be obtained. Sometimes, as at Kremnitz, the gangue consists partly of quartz and in part of indurated clay; in this case the most approved practice is, to raise the floor of the coffer to within about eighteen inches of the top, to put a moderate quantity of ore at once under the middle stamper, and to let on in the beginning of the process a full stream of water; by this the clay as being the softest is battered to pieces, and carried off by the water before the quartz is sufficiently comminuted to be washed out in any considerable proportion with it; the stream of water is then slackened, and the quartz is reduced to sand of the requisite fineness. There are few things that so much facilitate the washing subsequent to stamping, and upon which the product of metal so much depends, as the reduction of the gangue to grains of an uniform size; this is brought about by being careful that the ore when first put into the coffer, falls under the middle stamper, and

also by regulating the velocity of the water wheel; if the motion of the stampers is too slow, the only bad effect is loss of time; but when their action is too much accelerated, the water is dashed about and carries with it to the opening at the end of the coffer pieces of the ore that are not half ground, as well as those that have gone through the whole process: this fault is obvious not only from the difference in size between the grains, but those which have not been sufficiently pounded will be of a flat angular figure, and in consequence will remain behind with the metal in the subsequent washing, instead of being carried off the tables together with the rest.

When by the process of stamping, the ore is reduced to particles of sufficient fineness to be carried out of the coffer by the force of the water, it passes into shallow channels or troughs of various dimensions, constructed either of wood or stone, and communicating at their extremities with each other; the whole series is called a labyrinth. In these channels the various parts of the ore are deposited, according to their respective specific gravities; the heaviest particles being detained in the first, and the lightest subsiding in the last and lowest. Each of these channels is grooved at its lower extremity, to admit of its being closed at pleasure by pieces of wood about an inch in height, which slide down upon each other like the planks in a Chinese lock. It is obvious that the accuracy by which the heavy particles can thus be separated from the lighter ones, will be much modified by varying the rapidity of the stream through these channels, so that at its outlet the stream shall be swift and its velocity shall gradually decrease as it passes successively from one channel into another. This is effected by diminishing the slope and augmenting the width and length of the channels. Thus that which receives the water immediately from the coffer of the stamping mill is about four yards long, nine inches in depth and breadth, and has an inclination of two and a half or three inches; the second is about five yards long, twelve inches in depth and breadth, and has one inch of inclination; the third and fourth are six yards long, with a depth and breadth equal to the former, and an inclination of half an inch; the fifth is seven yards long, fourteen inches in breadth, twelve in depth, and is not inclined at all; the sixth is from eight to ten yards long, sixteen inches in breadth, twelve in depth, and like the former is entirely level. When these channels are about to be used a slider about an

inch high is put into the groove at the extremity of each, to prevent the grains which are deposited from being rolled out and washed away by the force of the water: when the deposit nearly attains the level of the top of the slider, a second is put in, and thus the process goes on till the channels are almost filled. The water from the coffer is now turned off into another labyrinth, and the contents of the former are taken out, care being taken not to mix what has subsided in any one channel with what has been deposited in the others. By means of the foregoing process, if carefully conducted, the metallic contents of the ore will be separated in a considerable degree from the lighter stony particles: every thing however depends upon the skill and accuracy of the manipulation, more especially where gold ores are thus treated, because in this case the proportion of gangue to the ore is greater than in any other, hence even a moderate degree of carelessness or of imperfection in the apparatus, will occasion a loss of full one fourth of the gold.

The first operation of washing, however carefully conducted, is by no means entirely adequate to the entire separation of the sand from the ore, it is therefore a second time washed on what are called tables. These are long planes of wood, considerably inclined (more or less according to circumstances) and crossed here and there at regular distances by narrow shallow grooves. To the upper extremity of the table is fastened a long wicker basket, or a perforated wooden trough, which is filled with washed ore; a little stream of water is then admitted, which passing between the twigs of the basket trickles down upon the table, carrying with it particles of the ore, which are either carried entirely off the table by the impulse of the water, or are deposited in the grooves according to their specific gravity, the heaviest particles being stopped the soonest. By this method the auriferous ores of iron and copper pyrites, galena, blende, &c. are sufficiently separated from the quartz and other stony matter to be fit for the smelting furnace; but the ores of native gold generally undergo a third washing, which is performed on small quantities at a time, in a wooden vessel called by English miners a buddle; its shape somewhat resembles that of a common fire-shovel without a handle, only the sides are more elevated in proportion, and it is furnished with two ears to hold it by. The ore being put in the vessel is gently immersed in water, and a circular motion is communicated to it by a peculiar flight of hand not to be described by words, by means of which the lighter particles

are by degrees thrown out of the buddle into the water, hardly any thing but the gold remaining behind, which is then either amalgamated or directly fused in an earthen crucible with the addition of a little nitre.

The gold that is found in alluvial soil or in the sands of rivers, is obtained in precisely the same way, except that it is not necessary to pass it through the stamping mill previous to washing.

The proper auriferous ores being lighter than gold, and their contents being rarely of sufficient value to admit of that accuracy in washing to which native gold is subjected, are always found after they come off the washing tables to be mixed with a very considerable proportion of stony matter. If the metallic part consists of pyrites, as is usually the case, it is advisable previous to fusion to give it a moderate roasting in order to drive off the greater part of the sulphur. The extent to which this process ought to be carried depends in some degree on the quantity and refractoriness of the stony part of the ore, for the sulphur in the subsequent fusion acting the part of a flux, it is obvious that the cleaner the ore is the more perfectly may it be roasted. This being finished, the ore is accurately mingled with a little quick-lime by way of flux, and with galena proportioned to the quantity of gold and silver that the pyrites contains according to the result of a previous assay. The mixture being now placed in a reverberatory furnace is made red hot, and as soon as it begins to clot together is stirred up from time to time and kept at a temperature inadequate to its fusion till part of the sulphur is driven off; this being effected the fire is increased, the whole is brought to a state of thin fusion and then let out in the usual way into a mould of sand. During the fusion the iron, on account of its powerful affinity for sulphur, resumes the portion of which it had been deprived by the previous roasting, by decomposing the sulphurets of lead and copper with which it is mixed, in consequence of which these metals by their specific gravity fall in drops through the vitreous ferruginous scoria, carrying with them the gold and silver, and unite at the bottom into a dense metallic mass. Hence the *pig* that is formed in the mould of sand is found to consist of two parts adhering to each other, but easily separable by a hammer; the uppermost and by far the largest portion is more or less cellular and consists of scoria, beneath which is a black heavy compact mass contain-

ing the gold and silver, together with lead, copper, some sulphur and iron. It is now broken into small pieces and roasted and fused once or twice more till all the sulphur and other impurities are got rid of, nothing remaining but the gold, silver, lead and copper.

§ 4. Refining.*

Although the refining of gold generally relates to the separation of this metal from silver and copper, these being the principal substances with which it is alloyed, yet it may with much propriety be considered as including all the methods of purifying gold from every other metallic admixture. In this sense the term is used on the present occasion, and we shall proceed to treat of it accordingly.

Separation of Gold from Lead and other metals by Cupellation.

The most economical method, and the only one habitually practised, of separating gold from lead is by a process called cupellation in the small way, and testing when practised on a large scale. The particular precautions requisite in cupellation are described under the article *ASSAY*, as the method of testing is under *SILVER*. All that is necessary to be stated here therefore, is merely the rationale of the process. The cupel or test is a porous infusible earthy mass, with a shallow concavity at the top for the reception of the metal: this being placed in a furnace so as not to be in contact with the burning fuel, and a current of air at the same time passing over the surface of the test, the metal is brought almost to a state of ebullition. At this temperature the lead is separated from the gold in the form of a vitreous oxyd, which sinking into the pores of the test leaves the gold behind nearly in a state of purity, this latter metal being incapable of oxydation at any temperature by simple exposure to heat and air.

Not only lead may thus be separated from gold, but its effect as a flux in scorifying and carrying down most of the imperfect metals is so great that by means of the process of cupellation with lead, repeated according to the proportion of the alloy and its affinity to the gold, these may also be got rid of nearly to the last atom. And this method is actually practised where the proportion of alloy is but small; when however it exceeds a certain ratio it is more economical to have recourse to the other methods detailed in this section.

It is to be observed however that when fine or pure gold is thus cupelled with lead, it always retains a small portion of this metal, which

* Lewis, Comm. tech. Gellert Chem. Metall. Fleeta minor.

however minute is sufficient to impair both its colour and ductility. If besides lead the mixture contains copper to the amount of one twenty-fourth of the gold, the whole of the lead will be separated but hardly any of the copper. If in addition to the above ingredients the alloy contains a somewhat greater proportion of silver than it does of copper, this latter is separated by cupellation and a little of the lead remains: but if the amount of silver is equal to or exceeds that of the gold, both the copper and lead may be completely worked off, the gold and silver remaining behind. Hence it is that the refiners in separating the base metals from gold by cupellation, always add to the mixture a considerable proportion of silver.

Cupellation with lead alone does not succeed when gold is alloyed with tin: in this case the tin with part of the lead forms a very spongy and refractory oxyd, which floats upon the surface of the melted metal and retains a part of the gold. This difficulty however is ingeniously obviated by the addition of some iron filings, which combine with the tin into an alloy that may be scorified by lead without any great trouble.

Separation of Gold from Antimony.

If the proportion of antimony exceeds that of the gold, the alloy, which will be very brittle, must be reduced to small pieces and mixed with about a fourth of its weight of sulphur and fused in a covered earthen crucible. When the fusion is complete it must be poured into a melting cone previously heated and greased, and when cool will be found to consist of two parts readily separable from each other; the upper will be sulphuret of antimony holding a very little gold; the lower will be the rest of the gold still combined with regulus of antimony. The greater part of the antimony being thus separated, the rest may be got rid of by melting the alloy at a high heat and directing a stream of air from a pair of bellows into a crucible containing it, by which the antimony is oxydated and volatilized in the form of a white vapour. Shortly after this appearance has ceased and the gold has acquired a clear bright green colour, it is to be poured out, and being then remelted in a smaller crucible, together with some nitre, the last portions of antimony, if any should happen to remain, will be completely oxydated and separated from the gold. The small quantity of gold detained in the sulphuret of antimony may be procured by bringing it into thin fusion and then precipitating part of the antimony by the addition of about

a fifth of its weight of iron filings: the gold will fall down together with the antimony, and may be separated in the way just described.

Separation of Gold from Silver and the imperfect metals by Sulphuret of Antimony.

By this method all the common imperfect metals except zinc may be separated from gold: for in the first place gold is incapable of combining with sulphur, and in the next place most of the other metals have a stronger affinity for sulphur than antimony has. It is obvious therefore that if to an alloy of gold and copper, for example, be added some sulphuret of antimony, the copper will become sulphuretted at the expence of the antimony, which in its turn will combine with the gold.

Earthenware crucibles are the only ones that can be employed where sulphuretted metals are concerned, but if these are used without any preparation they are extremely liable to crack and be corroded. The black-lead crucibles are fitter for this purpose than the common kind, but these last when prepared according to the method recommended by Scheffer are more durable and convenient than those of black-lead. The preparation is very simple: take a well-burnt crucible and soak it for two or three days in linseed oil, then clear away the oil to such a degree as that some finely pulverized glass of borax being dusted over the inner surface may just adhere, let it then be set by in a dry place for two or three weeks and it is ready for use. In such a crucible above two hundred fusions, according to Scheffer, may be performed in safety.

The gold alloy being melted in the crucible, there is thrown in at two or three different times, about twice its weight of coarsely pulverized sulphuret of antimony: at each addition the mixture froths and swells up so that the crucible must be large in proportion to the quantity contained; and especial care must be taken to prevent any pieces of charcoal from falling in, as this would infallibly cause the melted matter to run over. If the purity of the gold as previously found by the assay is less than 16 carats, the crude antimony before it is added should be melted with about a fourth of its weight of common sulphur, by which too large an addition of antimony to the gold is avoided. As soon as the mixture sparkles on the surface and is perfectly fluid, it must be poured into a melting cone previously heated and greased, and a tremulous motion by continued slight blows must be communicated to the mould to promote the settling of the precious

metal. When the matter in the cone is become solid, it may easily be got out by inverting the cone and giving it a few blows in this situation: it will be found to consist of a reguline mass of gold and antimony covered by a scoria composed of the former alloy of the gold united to the sulphur of the antimony. The gold however still retains a little of its alloy, and in consequence requires to be again melted a second or even a third or fourth time with the same quantity of sulphuret of antimony. From these last fusions the gold receives only a slight addition of antimony, as this metal unites with it only in proportion as it is deprived of its own sulphur by the small portion of alloy yet remaining in the gold. These processes being duly performed, the antimony is to be separated in the manner already described and the gold remains perfectly pure. Where the proportion of antimony is considerable, it is likely that its separation from the gold, which is usually a tedious business, might be expedited by a judicious fusion with sulphur, which converting part of the antimony into sulphuret would cause its spontaneous separation from the rest. The metals from which gold may be purified with particular advantage by means of antimony are iron, copper, tin, lead and silver.

Separation of a small quantity of Gold from a large quantity of Copper.

In old gilt copper wire, button-makers' clippings, and auriferous copper from Japan and other places, although the proportion of precious metal is too great to be neglected, yet it is by no means sufficiently large to admit of separation by the cupel or by sulphuret of antimony. The process of eliquation, or of fusing the copper with a large quantity of lead, and then exposing the mixture to a heat capable of melting out this latter while the former still continues solid, although practised with success in the separation of silver from copper has been repeatedly attempted in vain for the extraction of gold. But the following method, first published by Alonzo Barba, may on this occasion be resorted to with good effect.

Let the copper be first melted and granulated by being poured into water; then heat the metal red-hot in a crucible, and project on it at different times portions of common sulphur till the whole becomes black and brittle; then reduce it in a mortar or by any other convenient way to a fine powder and subject it to amalgamation in the same manner as the proper ores of gold; the mercury will dissolve out the whole of the latter metal without exerting the least action on

the sulphuret of copper, which may afterwards be brought to the malleable metallic state by roasting and fusion, as already described in the article copper.

There is another method however still more advantageous which may be employed for this purpose. Equal weights of sulphur and litharge are to be mixed together and combined by hasty fusion into a black sparkling mass: the gold-holding copper being then melted, the sulphuretted lead is thrown in by small quantities at a time till its amount nearly equals that of the copper. All the ingredients, in consequence of the lead being in the state of oxyd, unite together into an uniform mass. When the whole is in compleat fusion some finely pulverized charcoal is added at two or three several times, being carefully stirred in with a piece of strong copper wire. The charcoal immediately deoxygenates the lead, which sinking to the bottom in its metallic form, draws with it the whole of the gold also, leaving a scoria of sulphuretted copper floating on its surface. The gold is afterwards freed from the lead by cupellation.

This same process might no doubt be applied to the separation of gold from iron.

Separation of gold from Silver.

If the proportion of gold is very small, the best way of separating it from the silver is by means of sulphur. For this purpose the alloy is melted, and granulated by being poured into cold water kept constantly in agitation by a wicker brush or rod. Of the granulated metal from an eighth to a fifth is reserved, and the rest is well mingled with about an eighth of its weight of pulverized sulphur, which readily adheres to the moist grains. This mixture is put into a covered crucible and gently heated for some time, that the metal may be thoroughly penetrated by the sulphur: when this is effected, the fire is to be raised, and the mass brought into fusion. In these circumstances it might be thought that the gold, on account of its great specific gravity, having also no affinity with sulphuretted silver, would fall in drops to the bottom of the crucible, and there unite into a mass by itself. This however is not the case; the sulphuretted silver forms a tough viscous fluid, in consequence of which the minute grains of gold are prevented from subsiding. When therefore the mass has been in full fusion about an hour, so that the sulphur is compleatly united with the silver, and any accidental excess of it has burnt off, one third of the reserved silver in grains is added, and as soon as melted is stirred with a wooden rod in order to mix it

very accurately with the other materials and thus bring it in contact with the gold with which it immediately combines. After another hour of fusion, a like quantity of grained silver is again added, and an hour after this the remaining third. The crucible is now kept carefully covered, and at a pretty high temperature for about three hours, its contents being well stirred up from the bottom at least once every half hour. At the end of this time the surface of the mass instead of exhibiting the dark brown colour of sulphuretted silver, will have become whitish in consequence of the escape of part of the sulphur, and some bright white drops of melted silver of the size of peas will also appear. The matter must now be poured into a greased cone with the usual precautions, and when cold will be found to consist of a mass of sulphuretted silver, resting upon a white metallic button about equal in weight to the added silver, and containing the whole of the gold that was at first mixed with the entire mass. If the sulphuretted silver retains any gold, this may be separated by fusion in an open crucible: part of the sulphur burns off, and a corresponding quantity of silver is reduced to the metallic state: this being mixed with the rest by being carefully and repeatedly stirred with a piece of stick will attract the whole of the gold remaining in the silver that is still sulphuretted, and being poured into a cone will collect in one mass at the bottom.

The gold-holding silver collected in these two operations being melted and granulated, is subjected to one or more repetitions of the same process till the silver that is left contains a sufficient quantity of gold to make it worth while to proceed to parting by aqua fortis. It is possible indeed to separate nearly the whole of the silver by means of sulphur, but when the silver comes to be rich in gold, the sulphuretted silver always takes up a portion of it which is not separable again entirely without repeated fusions, so that when the gold amounts to a twentieth of the silver, it is scarcely advantageous to attempt a further purification by means of sulphur.

It appears from various experiments that the affinity of gold for copper, and of silver for lead is considerably greater than that which subsists between gold and silver, and upon this is founded a very ingenious and economical method of separating the gold from old gilt lace or silver wire, which has been practised in Saxony to a considerable extent. The metal being granulated, one sixteenth of it is mixed

with half its weight of litharge, and one eighth of sandiver, and is named the precipitating mixture: the next is mingled with an eighth of pulverized sulphur, and is brought into fusion in the same manner as already described. When the fusion is complete, which is known by a kind of flashing at its surface, half of the precipitating mixture is added at three different times, with an interval of about five minutes between each, and the fusion is then continued about ten minutes longer. Part of the sulphuretted silver is then laded out with a small crucible made red hot, and the remainder being poured into a melting cone, there subsides to the bottom a quantity of metallic silver combined with the greater part of the gold. The sulphuretted silver being again melted, the remainder of the precipitating mixture is added in the same manner as at first, and a second portion of gold holding silver is thus procured. The sulphuret still retains a small quantity of gold, in consequence of which it is a third time fused, and a precipitating mixture, equal in weight to the preceding, but composed of an alloy of equal parts of copper and lead, is added, by which a third precipitate of gold-holding silver is thrown down, and the sulphuret has now lost all its gold.

The several metallic masses thus procured are melted with an eighth part of lead, then granulated, and subjected to exactly the same treatment by sulphur and the precipitating mixtures as at first. The silver thus obtained being now very rich in gold is granulated, mixed with a sixteenth of sulphur, and kept in fusion for about half an hour, without the addition of any precipitant: being poured into a cone, the sulphuret is separated from the metal, and this last is treated twice or thrice more with sulphur in the same manner. The metallic button which now begins to exhibit a yellow colour, is melted with a sixteenth of copper, then granulated and mixed with a sixteenth of sulphur: this mixture being first gently heated in a covered crucible, and then fused for about a quarter of an hour, is poured into a cone, at the bottom of which the gold is found, of a brass colour, and about eighteen carats fine. Its purification is then completed by sulphuret of antimony, as we have already described.

When gold and silver are alloyed together in such proportions that the former of these metals is not much less than a sixteenth, nor greater than a fourth of the whole mass, the usual method of separating them is by means of nitrous acid, or aquafortis. The operation is

technically called *parting*, and differs from the process described under the same name in the article *ASSAY* only in being performed in larger quantities, and without some of those nice manipulations which are absolutely necessary to the accuracy of an assay.

Silver is readily dissolved in nitrous acid, while gold in ordinary cases is not at all attacked by this menstruum: in consequence of which when this latter metal amounts to one third of the mass, it combines with and protects by its own insolubility a portion of the silver from the action of the acid: hence the necessity of avoiding too large a proportion of gold in the alloy. On the other hand, as the expence of nitrous acid is considerable, it is requisite that the silver should be rich in gold, to render this process which is very convenient on many accounts, also economical. The refiner therefore will be careful not to use pure silver, but such as contains a little gold, in lowering the fineness of such as is too rich in gold to be successfully parted by itself, and by every other contrivance will study to employ no more acid than is absolutely necessary.

A proper selection being made of poor and rich ingots of mixed metal, the whole is melted in an iron crucible, and well mixed by repeated stirring: it is then laded out by a clean iron ladle, and granulated by being poured into cold water. The glasses in which the parting is performed, thence called parting glasses, are nearly of the figure of a truncated cone with a rounded bottom, about twelve inches high, and seven inches wide at the lower extremity: especial care must be taken in the choice of them, that they are without flaws of any kind, well annealed, and of an equal thickness throughout. Each glass is to be charged with about forty ounces of metal, to which is added nitrous acid, already half saturated with silver, in such quantity as to stand two or three fingers' breadth above the surface of the metal. Twenty or more of these glasses are placed in a sand-bath, and a moderate heat is applied, gradually increasing till by the time that the acid is saturated, it is nearly boiling. The nitrat of silver being now decanted off, a fresh quantity of stronger acid is added and is boiled on the metal till it is nearly saturated: by this time almost the whole of the silver is taken up, and the undissolved residue appears like a heavy brown mud, consisting of the gold divided into very fine particles, and a little silver. The nearly saturated acid is now poured off, and replaced by a third portion of still stronger pure nitrous

acid: this is made to boil, and is continued at the same temperature till the production of nitrous gas ceases and the bubbles become large, which is a sign that the whole of the silver is dissolved. The acid being poured out and reserved for the first part of a future similar process, the gold is washed with repeated portions of hot water, till the washings give no stain to a piece of polished copper on being dropped on its surface. The edulcorated gold-powder being dried, is mixed with a little nitre and borax and melted; and is then perfectly pure. The unsaturated nitrat of silver is reserved for the next parting: that which is saturated is poured boiling hot into a large wooden bowl lined with copper, and in which are laid several copper plates: upon these the silver is precipitated in the metallic state in consequence of the superior affinity of the acid for copper: the plates are from time to time cleared of their silver crust, in order to expose a fresh surface to the acid, and expedite the entire decomposition of the nitrat of silver: this being effected, the nitrat of copper is poured off, the plates are scraped, and the silver after edulcoration, is melted with a little nitre, and is thus obtained pure. If the nitrat of silver be perfectly neutralized, its decomposition by copper, goes on slowly and imperfectly: this inconvenience is however at once removed by the addition of a very few drops of nitrous acid. In proportion as the quantity of copper in the acid increases, and that of the silver diminishes, the remaining nitrat of silver requires more time and a greater heat to be decomposed, and even after long continued boiling with copper, a solution of any of the neutral muriats will throw down a white precipitate of muriated silver: it would appear therefore to be a saving both of time and expence, when the action of the copper begins to be languid, to throw down the remainder of the silver by an addition of common salt. The nitrat of copper obtained in the process of parting, is turned to good account by being employed in the preparation of *Verditer*, (see *COPPER*, p. 336.) and from the nitrat of lime resulting from this last, the acid is again procured by distillation in the usual manner with green vitriol or sulphuric acid.

Separation of Gold from Platina.

Platina being like gold one of the perfect metals, that is, unoxidable by simple exposure to heat and air, cannot be got rid of by cupellation; nor can any of the various methods in which sulphur or a sulphuretted metal is employed as the precipitant, be made use of with

success, for platina seems to have at least as little affinity for sulphur as gold itself has.

Mercury although capable of combining both with gold and platina, unites with the former much more readily than with the latter: upon this fact is founded a method of separating these metals, which though imperfect, may be advantageously applied as a preparatory process. When the gold contains so large a proportion of platina as to be brittle, it must be pulverized in a mortar; but if the alloy is ductile, it must be reduced to small pieces by granulation. This being done, some mercury, seven or eight times the weight of the alloy, is to be heated to ebullition in an iron crucible, and the alloy, previously made red hot, is to be dropped into it, and the whole kept in digestion nearly at the boiling point for half an hour. The mixture being then emptied into an iron mortar and covered with hot water, is to be carefully triturated for some hours, renewing the water from time to time: by this means the gold will combine with the mercury, and a considerable proportion of the platina will rise to the surface of the amalgam in the form of a black powder, which may readily be separated. When by this means the alloy is purified as much as possible, the superfluous mercury is separated by straining through a leather in the usual way, and the stiff amalgam is freed from the residual mercury by distillation.

The gold still holding a little platina, is now melted with thrice its weight of silver, and the mixture being granulated, is parted with aquafortis in the manner already described. Now it is a singular circumstance that although platina by itself, or even mixed with gold is perfectly insoluble in nitrous acid, yet when combined with a large proportion of silver, it is perfectly soluble in this menstruum, giving it a dark-yellowish brown tinge.^b When therefore this triple alloy is digested in nitrous acid, the silver and platina dissolve, leaving the gold behind. Of the gold thus separated and carefully washed, a few grains must be again melted with thrice their weight of silver, and treated with nitrous acid, in order to ascertain whether the platina is entirely got rid of; for if it contains $\frac{1}{2}$ per cent. or even less, the acid instead of being colourless, will be very sensibly tinged, in which case the process must be again repeated on the whole: this however is scarcely ever necessary where the previous trituration with mercury has been carefully performed. The silver contained in the nitrous solution, together

with the platina, cannot be separated by copper as is usual in common parting, because some of the platina would be precipitated at the same time; but if a solution of common salt is had recourse to, the silver will be thrown down in the state of muriat, and the platina will remain in solution.

Another and more compendious method of separating gold from platina, is to dissolve the alloy in nitro-muriatic acid, and to throw down the gold by the addition of carbonat of soda, or a large quantity of green sulphat of iron, neither of which will at all decompose the solution of platina: the gold when precipitated is to be dried, mixed with a little nitre and borax, and fused, after which it will be in a state of absolute purity.

Purification of Gold by Cementation.

A very few words are necessary on this subject, as the process is now we believe wholly obsolete. It has been already mentioned that nitrous acid is incapable of acting upon a small quantity of silver or copper or other metals, by which gold may happen to be alloyed, where the proportion of this latter is so great as to cover and envelope the particles of alloy. This takes place however only when the acid is liquid, and applied at a temperature not exceeding that of ebullition: at a greater heat a much larger proportion of gold is required to prevent the action of the acid on the base metal, so that by perseverance and judicious management the gold may be obtained nearly pure. The process by which this is effected is called cementation, and is thus performed.

Take the impure gold and beat or laminate it till it is somewhat thinner than a guinea; then heat it red hot, and allow it to cool slowly, that it may be as soft as possible; select a sound cementing pot, which is an earthen vessel shaped like a low hollow cylinder closed at one end, and cover its bottom to the height of about a finger's breadth, with a cement composed of one part of nitre, two parts of calcined sulphat of iron, and two parts of powdered tiles ground together to a fine powder, and moistened with urine; upon this cement place a single layer of gold plate, then another layer of cement, and so on alternately till the pot is full, observing that the upper as well as the under layer is of cement; then lute on very accurately a cover, and place the pot in a furnace, so that it may be kept at a moderate red heat for twenty-four hours, care being taken not to increase the temperature so as to endanger the

^b Vauquelin's Manuel de l'Essayer.

fusion of the gold. At this heat the metal being softened, and the acid being liberated in a very active state, the gold is penetrated more or less by it, and the silver and other metals, except platina, that the gold may contain are corroded and oxydated. When the pot is removed from the fire, it must be carefully unpacked, and the gold plates boiled first in water and then in dilute nitrous acid, by which they will be separated from the metallic salt and oxyd, and will be found when assayed to be considerably purer than at first. Every repetition of the process renders the gold purer, but in a decreasing ratio; so that it is not worth while to persevere in it longer than four or five times.

If common salt is substituted to nitre in the cement mentioned above, muriatic acid gas will be liberated instead of nitrous acid, and will be found to be equally efficacious, acting only on the alloy of the gold; but care must be taken not to employ both nitre and muriat of soda in the same cement, otherwise nitro-muriatic acid will be produced, and the gold as well as the alloy will be corroded.

The only purpose to which cementation is now applied, is to give a superficial and therefore in some measure fraudulent fineness to gold highly alloyed.

§ 5. *Physical properties of Gold, and preparation of Gold-leaf and Gilt-wire.*

The colour of pure gold by reflected light is a full bright yellow, verging on one hand towards orange, and on the other towards brassy-yellow: it is remarkable that gold fused with borax becomes considerably paler than usual, and on the other hand when fused with nitre, it becomes more highly coloured, without any other perceptible change being induced by either of these salts: hence as this metal is reckoned beautiful in proportion to the fullness and brilliancy of its colour, the borax flux used by the goldsmiths is generally mixed with a sufficient quantity of nitre to counterbalance its discolouring property. The colour of gold when in high fusion is blueish-green, of nearly the same tint with that of gold by transmitted light: this latter may conveniently be observed by laying a leaf of gold between two thin plates of colourless glass, and holding it between the eye and a strong light.

The specific gravity of gold is only inferior to that of platina: with regard to its precise amount a considerable variation may be observed on comparing the reports of different authors, one stating it as high as 20. and another as low as 18.75. This difference is no doubt

in part attributable to slight impurities in the gold itself, partly also to imperfection in the balances made use of, to differences of temperature, to the gold's being cast in sand or metal, to its being hammered or not, and to other causes which in the article *Alloy* we have briefly pointed out, as affecting the specific gravity of metallic substances. According to an experiment by Mr. Ellicot, whose accuracy is well known, the specific gravity of an ingot of gold refined by antimony, was = 19.184, and of the same when hammered, = 19.207. According to Lewis, the specific gravity of fine gold at 53° Fah. amounted to 19.376. Brisson reports the specific gravity of fine gold in ingot to be = 19.258, and of the same when hammered, = 19.361.

In hardness this metal ranks somewhat above silver and below copper. It is extremely flexible, and so tough, that when at length by repeated bendings it is made to break, both the fractured pieces appear terminated by a wedge-shaped extremity. From its softness and toughness it receives with perfect exactness the impression of the dies in coining, and for the same reasons it does not file freely, clogging up the teeth of the instrument in a very short time. It possesses little elasticity or sonorousness. It receives great brilliance from the burnisher, but not from the action of polishing powders. It is inodorous and insipid. The tenacity of gold is by no means so great as was supposed by the earlier chemists; it is inferior in this respect to iron, copper, platina, and silver. A wire of gold $\frac{1}{16}$ of an inch in diameter, will support about 254lbs avoirdupois, before it breaks. It is extremely malleable both when hot and cold, and very ductile.

In consequence of the high commercial value of gold, it is scarcely ever employed in mass, or in thick plates for ornamental purposes, but advantage has been taken of its remarkable malleability to reduce it into leaves of an almost incredible thinness, so that in this state notwithstanding its high specific gravity, it will float in the air like a feather. Of the ingenious art called *Gold-beating*, we shall proceed to give a short account.¹

The gold selected for this purpose is as pure as possible; the quantity used at one time by the English artists is two ounces. This being melted in a black lead crucible with some borax, is poured into an iron mould previously heated and greased, by which it is formed into a plate six or eight inches long, and three-quarters of

¹ Lewis Comm. Techn.

an inch wide. This plate is heated red hot, in order to burn off the tallow, and is then extended by forging on an anvil, and afterwards passed between steel rollers, till it becomes a long ribband as thin as paper. The ribband is now cut into 150 equal pieces, each of which is forged on an anvil, till it is about an inch square, after which they are well annealed. Each of the squares in this state weighs six grains and four tenths, and in thickness is equal to $\frac{1}{76}$ of an inch. The 150 plates of gold thus produced, are interlaid with pieces of very fine vellum about four inches square, and about twenty vellum leaves are placed on the outides, the whole is then put into a case of parchment, over which is drawn another similar case, so that the packet is kept close and tight on all sides. Being now laid on a smooth block of marble, from 200 to 600lbs. in weight, the heavier the better, the workman begins the beating with a round-faced somewhat convex hammer, called the *cutch* hammer, weighing sixteen pounds; the packet is turned occasionally upside down, and beaten with strong but not acute strokes, till the gold is extended nearly to an equality with the vellum leaves, to ascertain which the packet is opened from time to time, and also bent and rolled between the hands to facilitate the extension of the gold between the leaves. This first part of the process being completed, the packet is then taken to pieces and each leaf of gold is divided into four with a steel knife; the 600 pieces thus produced are interlaid with pieces of ox-gut, of the same dimensions and in the same manner as the vellum. The beating is continued, but with a lighter hammer called the *shoddering* hammer, and weighing about twelve pounds, till the gold is brought to the same dimensions as the interposed membrane. It is now again divided into four, by means of a piece of cane cut to an edge, the leaves being by this time so light that any accidental moisture condensing on an iron blade, would cause them to adhere to it. The 2400 leaves hence resulting are parted into three packets, with interposed membrane as before, and beaten with the *finishing* or *gold* hammer, weighing about ten pounds, till they acquire an extent equal to the former. The packets are now taken to pieces, and the gold leaves, by means of a cane instrument and the breath, are laid flat on a leathern cushion, and cut one by one to an even square, by a cane frame; they are lastly laid in books of 25 leaves each, the paper of which is previously smoothed and rubbed with red bole, to prevent them from

adhering. Hence it appears that each of the inch-square pieces, into which the ribband of gold was divided, is extended by beating to 196 square inches, or 16 leaves, weighing 0.4 of a grain each, and not exceeding in thickness $\frac{1}{150136}$ of an inch. Every grain of gold furnishes 30.6 square inches.

Gold wire, as it is called, is in fact only silver wire gilt, and is prepared in the following manner. A solid cylinder of fine silver weighing about twenty pounds, is covered with thick leaves of gold which are made to adhere inseparably to it by means of the burnisher: successive laminæ are thus applied, till the quantity of gold, if intended for common gold wire, amounts to 100 grains for every pound troy of silver; if for double gilt wire, to about 140 grains. This gilt silver rod is then drawn successively through holes made in a strong steel plate till it is reduced to the size of a thick quill, care being taken to anneal it accurately after each operation. The succeeding process is similar to the former, except that a mixed metal somewhat softer than steel is employed for the drawing plates, in order to prevent the gilding from being stripped off, and no further annealing is requisite after it is brought to be as slender as a crow-quill. When the wire is spun as thin as is necessary, it is wound on a hollow copper bobbin, and carefully annealed by a very gentle heat: finally it is passed through a flattening mill, and the process is complete.

According to Dr. Halley, six feet in length of the finest gilt wire before flattening, will counterpoise no more than a grain: and as the gold is not quite $\frac{1}{57}$ of the whole, a single grain of gold thus extended will be 345.6 feet long. By the operation of flattening, the length of the wire is increased about a seventh, and its width is equal to $\frac{1}{96}$ of an inch: hence the surface occupied by one grain is equal to 98.7 square inches, with a thickness of $\frac{1}{490444}$ of an inch.

§ 6. Chemical properties of gold.

Gold requires for its fusion a low white heat equivalent to 32° of Wedgwood, or 1300 of Fahrenheit, and in this state its surface appears of a luminous blueish green colour. It expands less than most metals by any addition of heat as long as it continues solid, but is enlarged more than any other during its passage from solidity to fluidity, hence it is peculiarly unfitted to take a sharp impression from casting, and hence also it is very apt to prove brittle if suddenly congealed, as by pouring into a cold mould. When divided into small parts, as

filings, and heated, although each particle is perfectly fluid, it is extremely difficult to make them unite into one mass without having recourse to some saline flux, and none is so efficacious for this purpose as borax, which accordingly is employed by the goldsmiths on all occasions, even when apparently it is not at all wanted. If cooled very slowly it shews a strong tendency to crystallization in the appearance of brilliant facets on its surface like the petals of a flower, and by pouring off the fluid part when it is half congealed, it may be obtained in short tetrahedral prisms. No vapour arises from gold when in fusion, and its remarkable fixity is proved by Kunckel who kept a quantity for almost thirty weeks in the high temperature of a glass-house furnace without the loss of a single grain, or any other alteration. When a small portion however is exposed in the focus of a very powerful lens, or subjected to the action of a stream of oxygen gas, it is volatilized unaltered and will gild a plate of silver held over it.

The possibility of altering gold by exposure to heat and air has long been a subject of controversy, nor do modern chemists seem by any means agreed on this point: there appears however no good reason to doubt that gold may be thus oxydated by particular management, though many of the facts usually brought in proof of it, are without question erroneous. Homberg affirms that a small quantity of gold placed upon charcoal and subjected to the action of a very powerful lens, began to smoke, and was in part vitrified. Of the fact there is no reason to doubt, but the vitrified portion in all probability consisted of the ashes of the charcoal, coloured by some of the alloy of the gold, as indeed was the opinion of some of the assistants at this very experiment. We have already cited the testimony of Kunckel to show the unalterability of gold, by the continued action of a high temperature, but the same chemist assures us, that this metal when prepared in a particular way, and exposed in fine powder to the action of a reverberatory furnace not sufficiently hot to melt it, is at length converted into an irreducible calx. It appears likely, that the preparation here alluded to, was alloying the metal, probably with tin: for in this state it is pulverizeable, and by a treatment similar to the one here mentioned, is entirely convertible into a spongy oxyd of a purple colour, and difficult reduction. This effect of the tin does not appear to be owing to any chemical action on the gold, but

merely to its separating the particles of this metal from each other, in which state it is reducible into a purple oxyd without much difficulty: for "if gold leaf be divided by grinding with an admixture of earthy powders, as calcined hartshorn and chalk, or with saline ones of the more fixed and less fusible kind, as vitriolated tartar, and exposed for sixteen or twenty hours to a moderate heat, scarce sufficient to keep the vessel red hot: the gold wholly loses its metallic brightness, and changes its yellow colour to a red or purple." * From this mixture the salt may be dissolved out by water, or the chalk by a weak acid, and the pure oxyd of gold remains behind. Gold may in like manner be converted into a purple oxyd by a strong discharge of electricity, as is manifest from the common experiment of passing a shock through gold-leaf laid between two plates of glass, and thus tinging the glass purple; and still more decidedly from an experiment of Van Marum, in which a gold wire was ignited by electricity, and volatilized with a green flame; the vapour being condensed, proved to be the purple oxyd of gold. The relative proportions of the two ingredients in this oxyd have not been ascertained. When exposed to a full red heat it is decomposed, the oxygen flying off, and the gold in its metallic state remaining behind.

If gold is precipitated by a fixed alkali from its solution in nitro-muriatic acid, a yellow oxyd falls down, which is supposed by Dr. Thomson to differ from the purple oxyd in containing a larger proportion of oxygen: no experiments have however as yet been instituted to ascertain this point. The yellow oxyd is reducible *per se* with the same ease as the other.

Gold in its metallic state appears to be acted on only by the following among the class of acids, viz. the nitric, nitro-muriatic, and oxy-muriatic acids.

Pure colourless *nitric* acid is incapable of dissolving reguline gold also pure: but if the acid is highly charged with red nitrous vapour, and in this state is digested on gold-leaf, in a retort or other close vessel, the metal is readily taken up. This fact was first discovered by Dr. Brandt in the following manner. Wishing to separate the silver from an alloy composed of 16 parts of silver and 3 of gold, he placed the mixture in an alembic with an attached receiver, and boiled on it successive portions of nitric acid, increasing the strength of it as he proceed-

* Lewis, p. 74.

ed: when nearly the whole of the silver was separated by this means, a fresh quantity of acid was added, and boiled nearly to dryness: this residue being mixed and boiled with more acid, a yellow coloured liquor was obtained, holding not only silver but gold in solution, as was evident from its depositing a considerable quantity of this latter in the metallic state, when digested with an additional portion of pure silver. By long keeping, part of the gold separated spontaneously in the form of a brown powder, but much still remained in solution as long as the external air was excluded. If some of this nitrat of gold be put into a vial and well shaken, so that the air which it contains is intimately mingled with the liquor, the gold according to an observation of Scheffer quickly and entirely separates from the acid.

The usual and most powerful solvent of gold is *nitro-muriatic acid*, prepared by adding to two parts of strong aquafortis, one of fuming muriatic acid, or one half part of common salt, or muriat of ammonia. The most economical, however, and upon the whole the best way of dissolving gold in this acid, is to put the granulated metal together with six times its weight of nitric acid, into a tubulated glass retort with a receiver annexed: the contents of the retort being warmed by a lamp, or a pot of charcoal, a little strong muriatic acid is to be poured in: an effervescence and copious extrication of nitrous gas will take place, and the gold will begin to be acted on: as soon as the gas ceases to be produced, a fresh quantity of muriatic acid is to be added, and so on till the gold is dissolved. The liquor being now made to boil, all the nitric acid which has escaped decomposition will distil over almost entirely unmixed with muriatic acid, a little of which last however will rise towards the end of the process in white fumes. Thus none of the nitric acid will be wasted, and the solution remaining in the retort will be pure muriat of gold. The colour of this solution is a bright yellow, it is very caustic, and has a strongly astringent metallic flavour. It gives a permanent deep purple stain to the fingers, and to almost all animal and vegetable substances; it even sinks deeply into marble, and communicates to it a similar tinge. In these cases the gold is no doubt converted into the purple oxyd. By slow evaporation and cooling, the liquor deposits small crystals of a yellow colour, in the form of four-sided prisms, or truncated octohedrons: these may be obtained with more certainty, if the

liquor after evaporation is diluted with a little warm alcohol. If the evaporation is very slow, and the light at the same time freely admitted, only a saline amorphous mass is deposited of a high red orange colour: nor can regular crystals be procured, according to Monnet, if either muriat of ammonia, or common salt enter into the composition of the aqua regia. By distillation at a very low red heat, muriat of gold is entirely decomposed, the acid escaping in the form of white vapour, and the metal in a reguline state remaining behind. If the salt has been prepared with *rough unsublimed* sal-ammoniac, and the heat is suddenly increased when nearly the whole of the liquid has been distilled off, there rises together with muriatic acid some very red muriat of gold, which dissolving in the fluid contained in the receiver, forms a ruby coloured liquor, named by the alchemists *leo ruber*, and supposed by them to possess many wonderful properties.

The alkaline earths both pure and carbonated, throw down from a solution of muriated gold, a yellow oxyd, which by exposure to the air acquires a purple colour, and at a red heat, is reducible *per se* to the reguline state.

The fixed alkalies precipitate the oxyd of gold in the form of a brownish yellow sediment, which when washed and heated becomes first purple and then assumes its metallic appearance. If a perfectly carbonated alkali is made use of, the only precaution requisite is to dilute the metallic solution with three or four times its bulk of water before pouring in the alkali, by which management, the subsidence of the precipitate will be expedited, more especially if the mixture is boiled for a minute in a glass-vessel. If however an alkali in part or entirely caustic, is made use of, care must be taken, after diluting the solution to drop in the alkali by degrees, and only so long as it causes a visible precipitation: if after standing twenty-four hours to allow the oxyd to subside, the supernatant liquor is still coloured, a little more alkali may be added. But if instead of this cautious proceeding, an excess of alkali is poured in at once, the liquor assumes a light purple tinge, some of the gold is redissolved by the alkali, and it will be several months before the whole of the metallic oxyd is separated.¹

In the decomposition of muriated gold by means of the fixed alkalies, the action of these substances appears to be confined to the saturation of the acid; and in consequence of the strong affinity subsisting between these two, the

¹ Beaumé Chim. exp. iii. p. 71.

oxyd of gold is precipitated, while the supernatant liquor holds in solution the neutral muriat. The metallic oxyd after being well washed seems to be perfectly pure, and is decomposable at a low red heat, merely in consequence of the very weak attraction of gold for oxygen. Ammonia differs in this respect very materially from the fixed alkalies: its affinity for the oxyd of gold is remarkably powerful, and in consequence, it decomposes the salts of this metal, not only by means of its affinity for the acid, but also for the base, hence the precipitate is not a mere oxyd, but an ammoniuretted oxyd, and it exhibits, as we shall proceed to show, very remarkable properties.^m

Ammoniuret of gold, or *fulminating gold*, is prepared in the following manner. To a solution of muriated gold, diluted with six or eight times its bulk of distilled water, add liquid ammonia drop by drop, till it ceases to occasion any precipitate: separate by means of the filter, the yellow powder that will be thus produced, wash it well in two or three parcels of hot water, and let it dry in the air or in a warm room. The fulminating gold thus procured, will be found to exceed the weight of the original gold by about 33 on the hundred, or in other words, out of 100 parts of this compound 75 will be gold. If a little of this powder, half a grain for example, is held over a candle, in a spoon or on the blade of a knife, it shortly explodes with a loud stunning report, from which circumstance it has obtained its common appellation.

Although the process which we have just given is perhaps the simplest method of preparing this dangerous salt, yet so powerful is the affinity of ammonia for oxyd of gold that if the two come into contact with each other under almost any circumstances, they will eagerly combine together. Thus if the gold instead of being dissolved in pure aqua regia is dissolved in one made by mixing nitric acid with muriat of ammonia, the precipitate thrown down from this even by a fixed alkali will possess the property of fulminating. Again, if oxyd of gold thrown down from pure aqua regia by a fixed alkali be redissolved in either the sulphuric or nitric acids and precipitated by ammonia, the result will be fulminating gold. If even the simple oxyd of gold, previously boiled with caustic fixed alkali in order to separate any adhering acid, be digested for some hours in liquid ammonia, it will become equally fulminating as by any other mode.

The effects of this compound when exploded, though not so violent as those of fulminating silver, are sufficiently dangerous to justify the greatest caution in using it. The precise degree of temperature requisite for its explosion is not ascertained, and indeed appears to be subject to some variation; it may however be stated as above 250° of Fahrenheit's thermometer. Just before it explodes, its colour changes from yellow to black, and a momentary flash is observable at the instant of its decomposition. Although it exerts its force in all directions, yet its principal energy is in a downward direction; hence two or three grains exploded on a piece of moderately thick sheet copper will tear a hole in it. An electrical shock will also decompose this salt, but it cannot be set fire to by a spark either of electricity or from the flint and steel. By sudden friction it explodes with great vehemence, and several instances are recorded of serious accidents from this cause: hence it should never be kept in a ground-stoppered bottle, as a little may adhere in the neck and will be infallibly exploded by the insertion of the stopper. The facility with which this powder explodes is prodigiously increased by high drying; if it is heated till it becomes black and is immediately removed from the fire, it will then go off frequently by a mere touch. The grains of this substance have not like those of gunpowder the property of communicating the decomposition from one to another; only those that are heated to the precise point are exploded, the rest are dispersed unaltered by the violence of the shock. Its proper explosive force, though attended with a loud report, seems however to be considerably inferior to that of gunpowder, hence if heated in a pretty strong close vessel it is completely decomposed but without any shock.

There appears to be no substance capable of separating the ammonia from the oxyd of gold after they are once united, and the only mode of decomposition is the application of such a heat as shall at the same time deoxygenate the gold and reduce the ammonia to its elementary parts. By a dry heat this decomposition is mostly rapid and explosive, but by the intervention of a hot liquid it is gradual and silent. Thus the fixed alkalies, whether caustic or carbonated, if diluted with water so that their boiling point is inferior to the heat required for the decomposition of fulminating gold, may be digested upon it without in the slightest degree impairing its characteristic property, but when

^m Bergman's Ess. II. p. 135. Baumé Chim. exp. Lewis comm. techn.

so far concentrated as to require a much higher temperature for their ebullition, they gradually decompose it without however disengaging any ammonia. In the same manner diluted sulphuric acid produces no effect, though when concentrated it effects a decomposition, but merely in consequence of the greater quantity of heat which it requires for ebullition. Nitric acid even when most concentrated boils at a lower temperature than is required for the decomposition of this salt, and therefore produces no effect on it. Muriatic acid sparingly dissolves it, but on the addition of a little fixed alkali lets it fall again unaltered.

If aurum fulminans be mixed with four or five times its weight of chalk, or sulphat of potash, or in short with any pulverulent substance neither fusible nor decomposable at a moderate temperature, and is exposed gradually to a low heat it will be quietly decomposed, nothing of the salt remaining behind but the purple oxyd of gold. A similar effect may be produced, only that remarkable caution is required, by heating the fulminating gold without any addition; as soon as it changes colour at all it is to be removed from the fire, and when cold again heated till the colour is a little more deepened, proceeding in this way till the powder becomes purple it will be found to have entirely lost its explosive faculty. A similar change takes place if some sulphur is melted at the lowest possible heat and the fulminating gold is dropped in by half a grain at a time and well mixed: the sulphur may then be burnt off without any danger, and minute grains of metallic gold will be left behind.

The true theory of the decomposition of fulminating gold was partially discovered by Bergman, and has since been fully illustrated by Berthollet. The former of these able chemists showed that this salt when decomposed in close vessels was reduced to gold partly in the metallic state and partly in that of purple oxyd, and at the same time a gas was extricated in bulk about a thousand times as great as that of the original fulminating salt, and which extinguished flame and animal life, was not absorbed by water and gave no precipitate with lime-water. Berthollet, by decomposing the same substance in a copper tube connected with a jar inverted in mercury, obtained azotic gas and a few drops of water, and the gold was reduced to the metallic appearance. Now as ammonia is composed of hydrogen and azot, and as the affinity of gold for oxygen is very

slight, it is manifest that the decomposition and explosion under the circumstances already mentioned, are occasioned by the oxygen of the gold and the hydrogen of the ammonia combining to form water, and to the liberation of the azot and its sudden assumption of the gaseous state.

Muriat of gold may be decomposed not merely by the superior affinity of certain substances for its acid, or of others for the metallic oxyd, but also in consequence of yielding a part of its oxygen to bases whose attraction for this substance is particularly powerful. Thus if a little muriat of gold is poured into sulphureous acid, this last in a short time deprives the metallic salt of part of its oxygen, and in consequence the surface of the fluid is covered with a film of reduced gold: the same takes place if gallic acid is made use of. So also if ether and muriat of gold are shaken together, the water first gives up the metallic salt to the ether and becomes itself colourless, while the ether assumes a bright yellow tinge, and after a while the gold is deoxydated by the combined action of the water and ether, and is separated in its metallic state. In the same manner a stick of phosphorus being immersed in muriat of gold will in a few days be covered with a brilliant coating of this metal: and a similar effect is produced, according to Count Rumford, by charcoal, provided its action is assisted by a boiling heat or by exposure in a closed vial to the rays of the sun. Hydrogen gas also is capable of decomposing muriat of gold as well as other metallic salts while they are moist with water; thus if a piece of silk is dipped in muriat of gold and exposed in a close vessel to hydrogen gas, it will in a short time be covered with a pellicle of gold, partly metallic and in part in the form of purple oxyd.

Certain of the metals and metallic salts decompose muriat of gold accompanied by peculiar phenomena, which we shall proceed to mention.

If a piece of clean iron is introduced into a dilute solution of muriated gold, this latter metal is precipitated upon the surface of the iron in the reguline state, a proportional quantity of the iron being dissolved. If the solution is largely diluted with alcohol instead of water, the gold precipitates upon the iron and a very little of this latter is in return taken up by the dulcified acid; the gold may be made to adhere firmly to the surface of the iron by burnishing, and this is the most convenient and economical method of gilding iron. The red sulphat of

iron, being fully charged with oxygen, has no effect on muriat of gold, but the green sulphat entirely decomposes it, being itself convertible to red sulphat and the gold falling down for the most part in the metallic state.

Copper acts with remarkable energy on muriat of gold: as soon as immersed in this fluid it becomes superficially of a blackish red colour, and after a while the gold subsides in its metallic state but with a reddish tinge, no doubt from its being mixed with copper. When the whole of the gold has fallen down the liquor becomes colourless, as was observed both by Lewis and Beaumé; this however does not prove that the solution contains little or no copper, as these chemists suppose, but the direct reverse; for when muriat of copper is at its minimum of oxydation, that is when it contains the greatest possible quantity of metal in proportion to its oxygen, the salt is entirely colourless, being the white sub-muriat recently discovered by Proust. Sulphat of copper is incapable of decomposing gold. Acetite of copper separates the gold in brilliant metallic films, which adhere to the sides of the vessel; in this case however it is probable that the acetic acid contributes to the decomposition at least as much as the copper.

Zinc, bismuth and mercury decompose the muriat of gold, throwing down the metal in the reguline state. The action of the salts of these metals on the same has not been examined into with any accuracy. Orschal^o says that nitro-muriat of mercury precipitates gold of a remarkably bright purple colour, superior in this respect to Cassius's precipitate.

Silver and lead precipitate the gold from its muriat in the form of purple oxyd. The same takes place when the nitrats of these metals are employed; a copious deposition of muriated lead or silver takes place mixed with the purple oxyd of gold. Tin likewise decomposes muriat of gold, and separates from it a purple oxyd. For this purpose let the metallic salt be largely diluted with water and put into a glass or glazed earthenware vessel together with a few pieces of grain tin: in a short time the liquor will become of the colour of red wine, and a very light flocculent precipitate will begin to separate, leaving the liquor entirely clear: this being poured on a filter and washed repeatedly with warm water is then to be dried; it now appears as a deep purple powder, and is used by enamellers and makers of artificial gems as the colouring matter for the finest red glass. A similar effect is produced by using recently made muriat

of tin instead of the pure metal, this salt having a remarkably strong affinity for oxygen, and therefore easily throwing down the gold in the state of red oxyd. Even nitro-muriat of tin, if newly made at a low temperature, will be nearly as efficacious as the simple muriat, and this method of preparing the purple colouring matter having been invented by Dr. Cassius more than 150 years ago, has since been familiarly known by the name of Cassius's purple powder or precipitate. The ancient method of preparing it was the following.^p Into about two quarts or more of distilled water, drop first about a scruple of a solution of gold in aqua regia, and then add a like quantity of a solution of tin in nitro-muriatic acid; when the purple precipitate thus produced has subsided a little, add a few drops more of tin as long as any further precipitate takes place; then throw the whole on a filter, wash it repeatedly and dry it. This mode however is liable to several objections: it very often happened that the tin was so highly oxygenated as to be wholly incapable of throwing down any precipitate; in this case the addition of some grains of metallic tin was requisite; but though this was effectual in decomposing the muriated gold, it also at the same time threw down some oxyd of tin which considerably impaired its use as a colour for transparent glasses. Sometimes, especially if the liquor was not enough diluted and the gold was added to the tin, instead of the tin to the gold, only a muddy bluish brown precipitate was obtained. Another inconvenience attending the practice of the ancient chemists in this matter was, that the aqua regia in which they dissolved the gold was almost always made with nitric acid and muriated ammonia, in consequence of which the red powder very often possessed a fulminating property, and thus occasioned many serious accidents.

Besides the nitric and nitro-muriatic acids, gold is also capable of being dissolved by the oxymuriatic acid. This fact was first ascertained by Scheele. The solution however when compleated appears to be merely muriat of gold, the superabundant oxygen being entirely employed in oxydating the gold previously to its becoming soluble in the acid, now changed into simple muriatic acid.

The oxyd of gold precipitated from the muriat by either of the carbonated fixed alkalies is soluble, as Bergman has shown, in the sulphuric and various other acids; but the salts hence resulting have not as yet been examined.

^p Sol sine veste; in Neri's Art. de la Verrerie.

^p Ibid.

Of the neutral salts nitre appears to be the only one capable of acting on metallic gold: on this subject Mr. Tennant has published the following interesting particulars.^a A golden tube was filled with nitre and thin pieces of gold, and exposed for two or three hours to a strong red heat; by this process part of the nitre was converted into caustic potash and part into nitre more or less deoxygenated, or according to the reformed nomenclature, nitrite of potash. Of the gold a considerable quantity was changed into a black powder, separable from the alkali and other saline matter by mere washing, but another portion of gold equal in weight to a fifth of the black powder, remained in solution, communicating to the liquor a yellow colour. By dropping into this solution diluted sulphuric or nitrous acid, it became at first of a deep yellow, but if viewed by transmitted light, it soon appeared green, and afterwards blue, from the gradual precipitation of the gold in its metallic state. But although the metal is thus precipitated in its reguline state, it appears while in solution, to be in the form of oxyd, and to be afterwards thrown down, only because its oxygen is gradually abstracted by that portion of nitre which has been partially decomposed. In proof of this, it may be further remarked, that even muriat of gold, if considerably diluted with water, is decomposable by nitre that has been partly deoxygenated by heat, the gold being precipitated in the *metallic* state, which could not happen if the alkali alone of the nitre had been concerned.

The affinity between gold and sulphur, if it exists at all, is never sufficiently efficacious to produce a combination between these two substances: but sulphuret of potash or soda will dissolve leaf gold by fusion without difficulty. The compound thus produced, is perfectly soluble in water, and may be passed through a filter without depositing any of the gold. The addition of an acid throws down both the sulphur and the gold: but whether this latter is in the state of hydrosulphuret or not, has not been ascertained: if the mixed precipitate is gently heated, the sulphur is evaporated or burnt off, and the gold in its metallic state remains behind.

The only one of the simple combustibles with which gold has hitherto been found capable of combining, is phosphorus. This fact appears to have been first noticed by Pelletier:† he mixed half an ounce of gold with an ounce of vitreous phosphoric acid and a drachm of char-

coal, and by heating the mass, inclosed in a crucible, for an hour in a furnace, he obtained a metallic button, weighing about four per cent. more than the gold employed, of a whitish colour, and exhibiting on its surface marks of crystallization: it was perfectly brittle, but by being kept for some time in fusion on a cupel, the phosphorus was burned off, and the gold resumed its usual characters. Phosphuret of gold may also be prepared by heating gold filings to redness in a crucible, and then dropping on them a few small pieces of phosphorus, the mass soon enters into fusion, and the result is a button of phosphuretted gold, resembling in every respect that procured by the former method. From these facts as ascertained by Pelletier, we may explain an experiment of Glauber, mentioned in his treatise *de lapide animali*, which has puzzled and has been called in question by many succeeding chemists. The experiment is this: two or three ounces of hartshorn are to be dissolved in nitro-muriatic acid, in which a drachm of gold-leaf is afterwards to be dissolved, by digestion in a glass cucurbit: the fluid being distilled off, the residue is to be fused quickly in an open crucible in a forge fire: the upper part will be found changed into a black scoria, beneath which the gold is found rendered white and brittle like regulus of antimony.

§ 7. Alloys of Gold.

Mr. Hatchett's valuable experiments on the alloys of gold as detailed in the Philosophical Transactions for 1803, have been consulted for most of the facts in the present section; those which have been obtained from other sources, will be noticed accordingly.

Arsenic, on account of its volatility, can be combined with gold only in small proportions. If the mixture is attempted to be made by projecting metallic arsenic on gold in fusion in an open crucible, the arsenic according to the quantity used, will be either entirely or in great part dissipated, and the gold in consequence will remain entirely unaltered or rendered more or less brittle. If a small crucible containing gold be inserted into a larger one containing arsenic, and an inverted crucible be luted on by way of a cover, and the apparatus be heated strongly in a wind furnace, the arsenic will be raised in vapour, and the gold being fused in this arsenicated atmosphere, will combine with a small portion of it. The alloy hence resulting is of a grey colour, a coarse granular fracture, and very brittle. A heat equal to that of

^a Phil. Trans. 1797. p. 219.

† Memoires I. p. 266. II. p. 25.

melting gold is by no means necessary to effect this combination, for if a plate of gold is merely brought to a full red heat in an atmosphere loaded with arsenic, this latter will unite superficially with the gold, and the alloy hence resulting being very fusible, will trickle in drops from the plate, till the whole of it is thus arsenicated. This alloy is scarcely decomposable by mere heat, and at a high temperature the arsenic that is driven off, carries a considerable proportion of gold along with it.

If antimony is mixed by fusion with either fine or standard gold in the proportion of even $\frac{1}{4}$ of a grain to the ounce ($\frac{1}{1920}$ of the whole mass) the resulting compound is brittle, has a close granular fracture, with hardly any metallic lustre, and its bulk will be found to be remarkably greater than would be deduced from the mean specific gravity of its ingredients.

Zinc forms with gold an alloy of a brass-yellow colour; in other respects its action on gold is very analogous to that of arsenic; when projected in small quantity on melted gold, it is entirely volatilized; in the state of vapour it combines with gold and renders it brittle. Fine brass added to gold in the proportion of $\frac{1}{24}$ forms a pale yellow brittle alloy, with a coarse granular fracture. The specific gravity of gold and zinc is somewhat greater than the calculated mean, where it forms $\frac{1}{12}$ of the mass. According to Hellot,^{*} an alloy of three parts of zinc, and one of gold, is somewhat malleable: and equal parts of the two metals form a compound which though brittle, is susceptible of a very high polish, and is but little liable to tarnish.

Cobalt mixed with standard gold, in the proportion of 4 grains to an ounce, renders the colour somewhat paler, and induces a slight degree of brittleness, but does not materially alter the specific gravity. When mixed with fine gold in the proportion of 38 grains to the ounce, the result is a pale yellow alloy, very brittle, and with an earthy fracture.

Nickel alloyed with gold in the proportion of 38 grains in the ounce, produces an alloy of the colour of fine brass, with a coarse grained earthy fracture, and very brittle: its specific gravity is less than the mean. If the nickel is reduced to eight grains in the ounce of standard gold, the alloy is only slightly brittle; and with 4 grains of nickel, the mixture continues perfectly ductile.

Gold may be alloyed with manganese by calcining the black oxyd of this metal repeatedly with oil in a covered crucible, and then exposing

it to a very high heat in contact with gold. The colour of the alloy thus produced is a reddish-grey; it is capable of receiving a brilliant lustre like steel; it is excessively hard, and is so far possessed of ductility, as to be in some measure flattened by the hammer before it breaks. The proportion of manganese thus combined is from $\frac{1}{8}$ to $\frac{1}{3}$ of the alloy. The gold in this mixture defends the manganese not only from being oxydated by the air, but also protects it from the action of all those acids in which gold itself is insoluble. By long exposure to a high heat with access of air, the manganese rises to the surface of the gold, where it becomes oxydated, leaving this latter metal behind quite pure. These two metals may in like manner be separated by cupellation with lead, or by solution in nitric acid, if the alloy has previously been parted with silver.

If gold is mixed with bismuth, in the proportion of 38 grains to the ounce, the result is an alloy of a pale greenish yellow, excessively brittle, and exhibiting a fine grained earthy fracture: its specific gravity is somewhat greater than the mean. If standard gold is alloyed even with $\frac{1}{4}$ of a grain of bismuth in the ounce, the mixture, although in colour and texture resembling standard gold, is yet perfectly brittle. So great is the liability of gold to be affected by bismuth, that if it comes in contact even with the fumes of this metal, and that not in close vessels, its ductility is entirely destroyed.

If lead is melted with gold in the proportion of 38 grains in the ounce, the alloy though externally resembling pale fine gold, is as brittle as glass; is of a pale brown colour internally; is wholly destitute of metallic lustre, and has a fine-grained porcellaneous appearance; its specific gravity is a little less than the mean. When the proportion of lead is reduced to $\frac{1}{4}$ of a grain in the ounce, the alloy is still perfectly brittle; and the fumes of this metal are nearly as prejudicial to the ductility of the gold as those of bismuth.

Tin when mixed with gold in the proportion of 38 grains in the ounce, forms an alloy of a pale yellowish-grey colour, with a fine somewhat earthy fracture; it may be bent without breaking, but is very little ductile: its specific gravity is considerably greater than the mean of the ingredients. An alloy composed of 19 grs. tin, 19 grs. copper, and the remainder of the ounce gold, has a coarse grained earthy fracture, and is considerably more brittle than if no copper had been made use of. An alloy com-

^{*} Lewis.

posed of 442 grs. in the ounce gold, 30 copper, and 8 tin, was of a somewhat paler colour than standard gold, but was perfectly ductile, and very soft. When it was exposed to a cherry-red heat, (10° Wedgw.) the surface began to be roughened by bubbles or blisters, then the bar began to warp on the edges, and lastly, when the whole of the tin diffused through the alloy, might be supposed to be in fusion, the bar fell by its own weight from the supporters on which it was placed, in a rough, dark coloured mass, having scarcely any appearance of a metal: it recovered however its lustre and some tenacity by being hammered on a polished anvil.^c

Iron, either in the state of bar iron, cast iron, or steel, may be combined with gold to the amount of 38 grains, and probably much more, in the ounce, without in the least degree impairing its ductility: the colour of the alloy is pale yellowish grey, approaching to dull white; it is considerably harder than standard gold, and its specific gravity is somewhat less than the mean of its constituent ingredients.

Platina and gold, when the proportion of the former amounts to 38 grains in the ounce, compose an alloy of a yellowish white colour, like tarnished silver, perfectly ductile, but much harder and considerably more elastic than standard gold. If to the foregoing alloy, the standard proportion of copper is added, the compound becomes of a pale dull yellow, and its ductility is somewhat diminished.

When gold is rendered standard by copper, that is, when the proportion of this last amounts to 38 grains in the ounce, the resulting alloy is of a deep yellow colour inclining to red; is harder than pure gold, but perfectly ductile. Its specific gravity is less than that of the mean of its ingredients in a remarkable degree. Equal parts of copper and gold also form a perfectly ductile alloy. It is not however every kind of reputedly pure copper which can safely be used for alloying gold: even the Swedish dollar copper occasionally renders the gold with which it is mixed, as brittle as glass: this appears to be owing to the lead and antimony which most copper contains, and which though not in sufficient quantity to affect in any material degree the ductility of the copper itself, are fully adequate to destroy the ductility of the gold with which they are mixed; since no more than $\frac{1}{1920}$ of either of these metals is enough for this purpose, as we have already mentioned.

Silver may be alloyed with gold in all proportions, and occasions hardly any perceptible

alteration of the ductility, hardness, or mean specific gravity; the colour of the mass becomes paler, exactly as the quantity of the silver is increased.

For the combination of gold with mercury, see MERCURY.

The chief use of gold is in coin: it is also applied in mass, in thread, and in leaf to many purposes of luxury and ornament. The purple oxyd is employed as a material for colouring glass and porcelain. The old chemists vaunted greatly its medical effects, but it has long since disappeared from every European pharmacopœa.

GOLD-BERYL. See CHRYSOBERYL.

GOLDEN SULPHUR OF ANTIMONY. See ANTIMONY.

GRADUATION of Saline Liquors. A method of concentrating weak saline solutions, by pouring them through a heap of faggots and exposing them in this divided state to a free current of air. For further particulars, see MURIAT of Soda.

GRAINE D'AVIGNON. See AVIGNON Berry.

GRAMMATIT. See TREMOLITE.

GRANAT. See GARNET.

GRANATIT. See STAUROLITE.

GRANITE. *Granite*. Fr. *Granit*. Germ.

Granite is a rock essentially composed of felspar, quartz, and mica, in grains or crystals of various magnitude. The parts of which it consists adhere to each other by the mere attraction of aggregation, and not by any paste or cement which binds them together, by which character this rock is distinguished from porphyry, as it is from gneiss by the absence of the slaty or schistose texture. Felspar is for the most part the predominating ingredient, and is not unfrequently in regular crystals; its colour is either milk-white, yellowish-white, honey-yellow, or flesh-red; when the crystals are very large they sometimes contain angular fragments of quartz, which from their resemblance to the Persepolitan characters, have obtained for this variety, among the French, the name of *pierre graphique*: in other varieties the felspar is found more or less deprived of its crystalline texture, and converted into indurated porcelain clay. The quartz in granite though seldom actually in crystals, possesses the transparency, fracture and other external characters that denote the crystalline texture; its colour is mostly a smoky yellow, of different degrees of intensity; sometimes though rarely it occurs of a fine granular texture and a snow-white colour. The mica

^c Bingley in Phil. Trans. for 1803, p. 75.

is in plates very various as to size, and in colour silvery white, smoky-brown, black, and green.

Granite (especially the large-grained which is generally esteemed to belong to the earliest formation) is often disposed in very thick and extensive beds or strata, hence it is found to split much easier in some directions than in others. The hardness and compactness of this rock vary extremely according to the perfection or tendency to decomposition of the felspar which it contains. The flesh-coloured can hardly ever be wrought without the help of gunpowder, but the white is often so rifted as to render blasting impracticable, at the same time that it still remains very difficult to work by the pick and other common instruments. Cavities sometimes of considerable magnitude are occasionally found in granite, lined with calcareous spar and colourless or amethystine crystals of quartz; and in the substance of the rock itself are contained various minerals besides the three of which it is essentially composed. When the proportion of mica is considerable, and the rock begins to pass into gneiss, it sometimes contains small garnets; when on the other hand the granite is very large grained, it abounds with crystals of black schorl. The other extraneous substances that it contains are beryl, hornblende, steatite, semi-opal, heavy-spar, and bitter-spath. It does not abound in metallic ores; hæmatite, tin-stone, galena, native silver, earthy cobalt, molybdena, bismuth and copper pyrites, have been found in granite, though in no great quantity.

Granite is reckoned the oldest of the primitive rocks, and is found in almost all the great mountainous chains, such as the Alps, the Pyrennees, the Crapack or Carpathian mountains, and the Norwegian mountains. In Britain, granite is found abundantly in the Grampians, and on the east coast of Scotland between the firths of Tay and Murray, at Portsoy in particular are vast quantities of *Pierre graphique*: at Mount Sorrel, in Leicestershire, is a low range of granite, and a little is to be met with in Shropshire. Wales contains none, with the exception of a narrow bank or two in Anglesey, but in Cornwall and the north of Devonshire, it is the common rock of the country.

The uses of granite are considerable; it is much employed in Scotland as a building material; it is the most durable substance that can be used for paving streets; and the ancients, especially the Egyptians, formed of it statues, obelisks, sarcophagi, and various other works of art.

GRANITE of Corsica. See MANDLSTEIN.
GRANULATION.

The process by which a metal is reduced into grains is called granulation. This is for the most part effected by melting the metal, and then pouring it in a very slender stream into cold water. As soon as the metal touches the water it divides into drops, which have a tendency to a spherical shape, and are more or less perfect according to the thinness of the stream, the height from which it falls, and the temperature both of the water and the metal. Tin, and some others of the most fusible metals, may be reduced to much finer grains than can be effected in the usual way, by pouring it when melted into a wooden box smeared on the inside with chalk, and shaking it violently before it has time to become solid. By this means tin is reduced to a fine powder; and there is no doubt but that the less fusible metals might likewise be so pulverized by a similar manipulation.

GRAPHITE, or Plumbago. See COAL.
Species ix.

GRAUSTEIN. See TRAP.

GRAUWACKE.

This name, for which we have no corresponding English term, is employed by the German mineralogists to denote a species of rock belonging to the more recent of the Transition class, and of which there are two very distinct varieties.

Common Grauwacke is composed of grains of quartz, siliceous schistus and slate or argillite, agglutinated by an argillaceous cement; the grains vary from the size of a pin's head to that of a hazlenut.

Slaty Grauwacke, is a simple schistose rock, which at first sight might be confounded with argillite, but upon a nearer inspection will be found to differ in colour which is of a dirty grey, in being entirely destitute of lustre, in containing spangles of mica, which true slate never does, in its geological situation, and in its being never divided by beds of chlorite slate or Whetstone slate.

Both varieties of grauwacke are traversed by veins of quartz in various directions, and contain occasionally shells and vegetable remains: they never contain beds of other kinds of rock. They are never distinctly stratified, but their inclination is never parallel with that of the rock on which they rest.

Grauwacke contains sometimes beds of glance coal, and is rich in metallic ores; the mines of lead and silver in the Hartz, and some of the gold-mines in Transylvania, are in this rock.

GREEN EARTH. * *Terre verte.* Broch. *Grünerde.* Emmerl.

The colour of this mineral is celandine green of various shades, passing into mountain and blackish-green, rarely into olive-green. It occurs in mafs, in angular or globular pieces, or diffeminated, or as a superficial covering to balls of agate, or lining the empty cavities in amygdaloid. Its fracture is fine grained earthy, passing into flat conchoidal; it has no lustre; it breaks into indeterminate blunt-edged fragments. It gives a shining streak; is smooth and somewhat unctuous to the touch; is very soft; opaque; adheres slightly to the tongue; is light and easily frangible.

When exposed to the blow-pipe it blackens, but does not melt by itself: with borax it gives a brownish-black opaque glass; when immersed in water it absorbs a considerable quantity, but does not break down in it, or become plastic.

It is found wherever amygdaloid occurs, as in Saxony, Bohemia, Monte Baldo near Verona, Scotland, &c. When of a good colour it is made some use of by painters.

GRUNERDE. See GREEN EARTH.

GRUNSTEIN. See TRAP.

GUM-ELASTIC. See CAOUTCHOUC.

GUM-MUCILAGE. See MUCILAGE.
(*Vegetable.*)

GUM-RESIN.

These are for the most part the juices of various trees of tropical climates, which ooze out from natural cracks in the bark, or artificial incisions, and harden by the sun and air into irregular roundish masses. The gum-resins therefore are the juices of the respective plants as nearly as possible in their natural state, and they retain the sensible properties of smell and taste for a very great length of time. A similar juice, but inferior in quality, may also be obtained from some of them by macerating in water the entire vegetable, or part of the vegetable that yields it, and evaporating the water to an extract, but this is very seldom practised.

The gum-resins are almost exclusively employed in medicine, and only a very few of them have engaged the attention of chemists. Though they agree in those leading characters which constitute a *gum-resin*, there is a vast difference in the composition of the several species when examined chemically, and they pass almost by imperceptible gradations either into the pure resins, or into the extracts and gummy mucilages.

Of the most important gum-resins may be

enumerated, myrrh, galbanum, asafoetida, ammoniacum, olibanum, sagapenum, and perhaps opium. The chemical analysis of these and others where it presents any important results, will be given under the respective articles.

The general or characteristic properties of a *gum-resin* are (as its name imports) such as would be produced by a natural mixture of gum and resin. To the resinous part they chiefly owe the property of burning with much flame, melting in drops by the heat; of giving by distillation a large portion of volatile oil and some ammonia. To the gummy part they owe their partial solubility in water, so that when rubbed with this fluid they form an emulsion, generally whitish, which remains a considerable time turbid, and even when by rest the gum resin has again subsided, the clear liquor always retains some of the taste and smell of the substance employed.

Some of the gum-resinous juices are also mixed with a kind of EXTRACT, or a coloured and bitter substance soluble in water and alcohol, and also TAN is very commonly united to them. On the whole the term Gum-Resin is more properly a pharmaceutical than a chemical distinction.

GUNPOWDER. *Poudre a Canon.* Fr. *Das Schießpulver.* Germ.

Is a mechanical mixture of nitre, charcoal, and sulphur, the explosive powers of which are familiar to every one. The method of manufacture is extremely simple, but considerable precautions are necessary in the selection of pure and good materials, in ensuring a very intimate admixture, and in avoiding any strong collision or any other event which might produce fire, and thus kindle the powder, and be productive of the most dreadful accidents.

The actual mode of making gunpowder in England (and in all countries it is essentially the same) cannot be better described than from the account given by Mr. Coleman, of the Royal Powder Mills of Waltham Abbey, about twelve miles north of London.* The ingredients of gunpowder are taken in the following proportion, namely, 75 of saltpetre, 15 of charcoal, and 10 of sulphur. The saltpetre used is almost entirely that which is imported from the East Indies, which comes over in the rough state mixed with earthy and other salts, and is refined (in the manner described under the article NITRAT of Potash) by solution, evaporation, and crystallization. After this it is fused in a moderate heat, so as to expell all the pure water,

* Emmerl. Jameson, Brochant.

* Phil. Mag. Vol. ix.

but none of the acid, and is then fit for use. The great use of refining the nitre is to get rid of the deliquescent salts, which by rendering the powder made of it liable to become damp by keeping, would most materially impair its goodness. The sulphur used is imported from Italy and Sicily, where it is collected in its native state in abundance. It is refined by melting and skimming, and when very impure, by sublimation. It should seem that the English sulphur, extracted in abundance from some of the copper and other mines, is too impure to be economically used for gunpowder, requiring expensive processes of refining.

The charcoal formerly used in this manufacture near London (and still used in most parts of the world) was prepared in the usual way of charring wood, piles being formed of it and covered with sods or fern, and suffered to burn with a slow smothering flame. This method however cannot with any certainty be depended on to produce charcoal of an uniformly good quality, and therefore a most essential improvement has been adopted in this country, to which the present superior excellence of English powder may be in a good measure attributed, which is, that of enclosing the wood, cut into billets about nine inches long, in iron cylinders placed horizontally, and burning them gradually to a red heat, continuing the fire till every thing volatile is driven off, and the wood is completely charred. But as the pyroligneous acid, the volatile product of the wood heated *per se*, is of use in manufacture, it is collected by pipes passing out of the iron cylinder, and dipping into casks where the acid liquor condenses. This acid is used in some parts of calico-printing, chiefly as the basis of some of the iron liquors and mordants for dark-coloured patterns. The wood before charring is barked. It is generally either alder or willow, or dog-wood, but there does not appear any certain ground for preferring one wood to another provided it be fully charred.

The above three ingredients being prepared, they are first separately ground to fine powder, then mixed in the proper proportions, after which the mixture is fit for the important operation of thoroughly incorporating the component parts in the mill. A powder mill is a slight wooden building, with a boarded roof, so that in the event of any moderate explosion, the roof will fly off without difficulty, and the sudden expansion will thus be made in the least mischievous direction. Stamping mills were formerly used here, which consisted simply of a

large wooden mortar, in which a very ponderous wooden pestle was made to work, by the power of men, or horses, or water, as convenience directed. These performed the business with very great accuracy, but the danger from over-heating was found to be so great, and the accidents attributable to this cause were so numerous, that stamping mills have been mostly disused in large manufactures, and the business is now generally performed by two stones placed vertically, and running on a bed-stone or trough.

The mixed ingredients are put on this bed-stone in quantities not exceeding 40 or 50 pounds at a time, and moistened with just so much water, as will bring the mass in the grinding to a consistence considerably stiffer than paste, in which it is found by experience that the incorporation of the ingredients goes on with the most ease and accuracy. These mills are worked either by water or horses.

The composition is usually worked for about seven or eight hours before the mixture is thought to be sufficiently intimate, and even this time is often found by the inferior quality of the powder to be too little. The fine powder manufactured at Battle in Sussex, is still however made in large mortars or stamping mills, in the old way, with heavy lignum-vitæ pestles. Only a very few pounds of the materials are worked at a time.

The composition is then taken from the mills and sent to the *corning-house*, to be corned or grained. This process is not essential to the manufacture of perfect gunpowder, but is adopted on account of the much greater convenience of using it in grains than in fine dust. Here the stiff paste is first pressed into hard lumps, which are put into circular sieves with parchment bottoms, perforated with holes of different sizes, and fixed in a frame connected with a horizontal wheel. Each of these sieves is also furnished with a *runner* or oblate spheroid of lignum vitæ, which being set in motion by the action of the wheel, squeezes the paste through the holes of the parchment bottom, forming grains of different sizes. The grains are then sorted and separated from the dust by sieves of progressive dimensions.

They are then *glazed* or hardened, and the rough edges taken off, by being put into casks, filling them somewhat more than half-full, which are fixed to the axis of a water-wheel, and in thus rapidly revolving the grains are shaken against each other and rounded, at the same time receiving a slight gloss or glazing.

Much dust is also separated by this process. The glazing is found to lessen the force of the powder from a fifth to a fourth,^b but the powder keeps much better when glazed, and is less liable to grow damp.

The powder being thus corned, dusted and glazed, is sent to the stove-house and dried, a part of the process which requires the greatest precautions to avoid explosion, which in this state would be much more dangerous than before the intimate mixture of the ingredients.

The stove-house is a square apartment, three sides of which are furnished with shelves or cases, on proper supports, arranged round the room, and the fourth contains a large cast-iron vessel called a *gloom*, which projects into the room, and is strongly heated from the outside, so that it is impossible that any of the fuel should come in contact with the powder. For greater security against sparks by accidental friction, the glooms are covered with sheet copper, and are always cool when the powder is put in or taken out of the room. Here the grains are thoroughly dried, losing in the process all that remains of the water added to the mixture in the mill, to bring it to a working stiffness. This Mr. Coleman finds to be from three to five parts on 100 of the composition. The powder when dry is then complete.

The government powder for ordnance of all kinds as well as for small arms, is generally made at one time, and always of the same composition, the difference being only in the size of the grains as separated by the respective sieves.

A method of drying powder by means of steam-pipes running round and crossing the apartment has been tried with success: by it all possibility of an accident from over-heating is prevented. The temperature of the room when heated in the common way by a gloom-stove is always regulated by a thermometer hung in the door of the stoves.

The strength of the powder is sometimes injured by being dried too hastily and at too great a heat, for in this case some of the sulphur sublimes out (which it will do copiously at a less heat than will inflame the powder) and the intimate mixture of the ingredients is again destroyed. Besides if dried too hastily, the surface of the grain hardens leaving the inner part still damp.

Mr. Coleman deduces from experiment the following inferences, namely: that the ingredients of gunpowder only pulverized and mixed have but a very small explosive force: that gun-

powder granulated after having been only a short time on the mill, has acquired only a very small portion of its strength, so that its perfection absolutely depends on very long-continued and accurate mixture and incorporation of the ingredients: that the strength of gunpowder does not depend on granulation, the dust that separates during this process being as strong as the clean grains: that powder undried, is weaker in every step of the manufacture than when dried: and lastly, that charcoal made in iron cylinders in the way already mentioned, makes much stronger powder than common charcoal. This last circumstance is of so much consequence, and is so fully confirmed by experience, that the charges of powder now used for cannon of all kinds have been reduced one-third in quantity, when this kind of powder is employed.

In barrelling powder, particular care must be taken to avoid moisture, and this business is also generally reserved for dry weather.

When powder is only a little damp, it may be restored to its former goodness merely by stoving, but if it has been thoroughly wetted, the nitre (the only one of the ingredients soluble in water) separates more or less from the sulphur and charcoal, and by again crystallizing cakes together the powder in whitish masses which are a loose aggregate of grains covered on the surface with minute efflorescences of nitre. In this case the spoiled powder is put into warm water entirely to extract the nitre, and the other two ingredients are separated by straining and thrown away.

The specific gravity of gunpowder is estimated by Count Rumford^c to be about 1.868.

The strength and goodness of powder is judged of in several ways, namely, by the colour and feel, by the flame when a small pinch is fired, and by measuring the actual projectile force by the *eprouvette*, and by the distance to which a given weight will project a ball of given dimensions under circumstances in all cases exactly similar.

When powder rubbed between the fingers easily breaks down into an impalpable dust, it is a mark of containing too much charcoal, and the same if it readily soils white paper when gently drawn over it. The colour should not be absolutely black, but is preferred to be more of a dark blue with a little cast of red. The trial by firing is thus managed; lay two or three small heaps of about a dram each on clean writing paper, about three or four inches asunder, and

^b Napier, Irish Transactions.

^c Essays.

fire one of them by a red-hot iron wire: if the flame ascends quickly with a good report, sending up a ring of white smoke, leaving the paper free from white specks and not burnt into holes, and if no sparks fly off from it, setting fire to the contiguous heaps, the powder is judged to be very good, but if otherwise, either the ingredients are badly mixed or impure.

The common *eprouvettes* or powder-tries are small strong barrels, in which a determinate quantity of the powder is fired, and the force of expansion measured by the action excited on a strong spring or a great weight.

Another method often adopted is to fire a very heavy ball from a short mortar with a given weight of the powder and to find the range of projection.^d The French *eprouvette* for government powder is a mortar of 7 inches (French) in calibre, which with three ounces of powder should throw a copper globe of 60 lbs. weight to the distance of 300 feet. No powder is admitted which does not answer this trial.^e

Both these methods have been objected to, the former because the spring is moved by the instantaneous stroke of the flame and not by its continued pressure, which is somewhat different; and the other on account of the tediousness attending its use when a large number of barrels of powder are to be tried. Another method which unites accuracy with dispatch, is to suspend a small cannon as a pendulum, to fire it with powder only, and to judge of the force of explosion by that of the recoil, which in this circumstance is a greater or less arc of a circle. That which Dr. Hutton employs on this principle is a small cannon about one inch in the bore, the charge of which is two ounces of powder.

The cause and measure of the explosive force of fired gunpowder has been much investigated. It is generally allowed to be chiefly owing to the sudden generation of a quantity of gas or elastic vapour, the chemical constitution of which will be presently mentioned.

To determine the elasticity and quantity of this elastic vapour produced from a given quantity of powder, Mr. Robins^f premises that its elasticity is equally increased by heat and diminished by cold as that of common air (which is confirmed by Mr. Dalton's late experiments), and consequently its weight is the same with the weight of an equal bulk of air at the same elasticity and temperature. Hence, and from direct experiments, he concludes that the elastic fluid produced by the firing of gunpowder is nearly

$\frac{1}{10}$ of the weight of the powder itself, which expanded to the rarity of common air is about 244 times the bulk of the powder. Hence it would follow that the mere conversion of confined powder into elastic vapour would exert against the sides of the containing vessel an expansive force 244 times greater than the elasticity of common air, or in other words, than the pressure of the atmosphere. But to this is to be superadded all the increase of expansive power produced by the heat generated, which is certainly very intense, though its exact degree cannot be ascertained. Supposing it to be equal to the full heat of red-hot iron, this would increase the expansion of common air (and also of all gases) about four times, which in the present instance would increase the 244 to nearly 1000, so that in a general way it may be assumed that the expansive force of closely confined powder at the instant of firing is 1000 times greater than the pressure of common air: and as this latter is known to press with the weight of $14\frac{1}{4}$ pounds on every square inch, the force of explosion of gunpowder is 1000 times this, or, 14750 lb. or about six tons and a half on every square inch. This enormous force, however, diminishes in proportion as the elastic fluid dilates, being only half the strength when it occupies a double space, one-third of the strength when in a triple space, and so on.

Mr. Robins found that the strength of powder is the same in all variations of the density of the atmosphere, but not so in every state of moisture, being much impaired by a damp air, or with powder damped by careless keeping or any other cause, so that the same powder which will discharge a bullet at the rate of 1700 feet in a second in dry air, will only propel it about 1200 feet when the air is fully moist, and a similar difference holds between dry and moist powder.

A very considerable variation is found in the proportions of the ingredients of the powder of different nations and different manufactories, nor is it exactly ascertained whether there is any one proportion which ought always to be adhered to and for every purpose. The government powder made in this country is the same for cannon as for small arms, the difference being only in the size of the grains, but in France it appears that there were formerly six different sorts manufactured, namely, the strong and the weak cannon powder, the strong and the weak musquet powder, and the strong and the weak pistol powder. The following are the propor-

^d Encycl. Arts and Metiers.

^e Hutton's Mathemat. Dict.

^f A Treatise on Gunnery, or Hutton's Dicty.

tions in each, though the reason of this nicety of distinction is not very obvious. For the strong cannon powder the nitre, sulphur, and charcoal were in the proportions of 100 of the first, 25 of the second, and 25 of the third: for the weak cannon powder, 100, 20, and 24: for the strong musquet powder, 100, 18, and 20; for the weak, 100, 15, and 18: for the strong pistol powder, 100, 12, and 15; for the weak, 100, 10, and 18.

The Chinese powder appears by the analysis of Mr. Napier to be nearly in the proportions of 100 of nitre, 18 of charcoal, and 11 of sulphur. This powder which was procured from Canton was large-grained, not very strong, but hard, well-coloured, and in very good preservation.

The sulphur is not (properly speaking) a necessary ingredient in gunpowder, since nitre and charcoal alone well mixed will explode, but the use of the sulphur seems to be to diffuse the fire instantaneously through the whole mass of powder. But if the following experiments are correct, it should seem that the advantage gained by using sulphur in increasing the force of explosion only applies to small charges, but in quantities of a few ounces the explosive, or at least the *projecting* force of powder without sulphur, is full as great as with sulphur.

The following are a few out of many trials made at the Royal Manufactory at Essone, near Paris, in the year 1756, to determine the best proportions of all the ingredients. Of powder made with nitre and charcoal alone, 16 of nitre and 4 of charcoal was the strongest, and gave a power of 9 in the eprouvette. With all three ingredients, 16 of nitre, 4 of charcoal, and 1 of sulphur, raised the eprouvette to 15, and both a less and a greater quantity of sulphur produced a smaller effect. Then diminishing the charcoal, a powder of 16 of nitre, 3 of charcoal, and 1 of sulphur gave a power of 17 in the eprouvette, which was the highest produced by any mixture. This last was also tried in the mortar-eprouvette against the common proof powder, and was found to maintain a small superiority. The powder made without sulphur in the proportions above indicated was also tried in the mortar-eprouvette, and with the following singular result: when the charge was only two ounces it projected a sixty pound copper ball 213 feet, and the strongest powder with sulphur projected it 249 feet; but in a charge of three ounces, the former projected the ball 475 feet and the latter only 472 feet: and on the other hand the great inferiority of force in the smaller

eprouvette of the powder without sulphur has been just noticed.

Gunpowder is reckoned to explode at about 600° Fahr. but if heated to a degree just below that of faint redness, the sulphur will mostly burn off, leaving the nitre and charcoal unaltered. The gasses produced by the explosion of powder have not been analyzed with accuracy since the discovery of all the varieties of gasses with the basis of carbon, but they are certainly carbonic acid, sulphureous acid gas, and carburetted hydrogen. The residue is chiefly a sulphuret of potash formed by a part of the sulphur uniting with some of the alkali of the nitre, and hence the hepatic smell of a foul and damp gun-barrel.

The analysis of gunpowder performed with sufficient accuracy for most practical purposes is very easy and simple, but an absolutely accurate analysis is more difficult. The usual way is first to boil the powder with three or four times its weight of water, edulcorating it with more hot water till no saline taste remains. This extracts the nitre only, the quantity of which may be either ascertained by drying the residue and estimating as nitre all the loss of weight, or more directly by evaporating the watery solution. If the residue, consisting of the sulphur and charcoal, is now spread on a earthen plate of any kind and slowly heated, the sulphur takes fire and burns off gradually, whilst the charcoal remains untouched, when the heat is kept down sufficiently. Beaumé found however that when all the sulphur is expelled which will be driven off in this heat, a certain portion will still remain and will not burn away at a lower temperature than will consume the charcoal, so that to the last the burning residue will smell strongly sulphureous. This retained portion of sulphur he finds by the results of many other experiments to be very uniformly about one twenty-fourth part of the whole sulphur employed, whence for all common purposes an adequate correction may be made by estimating that the slow weak combustion of the residue, after the nitre has been got out, destroys only $\frac{2}{4}$ of the sulphur instead of the whole. On trying to separate them by an alkaline solution, he found some of the sulphur to remain undissolved and still adhering to the charcoal. The way to ensure perfect accuracy in analysis would be first to separate the nitre by hot water, then to acidify all the sulphur by the nitric acid, to dissolve and to precipitate it by a solution of nitrat or muriat of barytes, and from the known constituents of this salt to find

the quantity of sulphur, whilst the charcoal here remains perfectly untouched.

The discovery of the astonishing fulminating property of the salts with the OXYMURIATIC acid led several chemists to the idea of substituting the oxymuriat of potash to the nitre in the manufacture of gunpowder, and experiments have been made on a sufficient scale to shew that this gunpowder far exceeds the common powder in energy of explosive power. The oxymuriats however appear to act in a different manner from the mixtures with nitre, and to exert all their power extremely suddenly and in a very small space, so as to destroy every substance in immediate contact with them at the time of explosion, but to be inferior in projectile force to common gunpowder. All the explosive compounds with the oxymuriats have also the very dangerous property of exploding with very moderate friction, and hence they have never been employed in the large way.

GYP SUM.

Of the mineral species there are two families characterized by the presence or absence of water of crystallization.

1st FAMILY. Affords by distillation about 20 per cent. of water; and at a temperature below a red heat becomes an opaque white powder.

1. Subspecies. SELENITE. *Chaux Sulfatée*. Haüy. *Broad-foliated Gypsum*. Kirw. *Sélénite*, Broch. *Selenite*. Jameson. *Spathiger Gips*. Emmerl. *Frauenfels*. Wern.

It is either colourless, or yellowish and greyish white, smoky-grey; wax, honey, and ochre-yellow and yellowish-brown: it also not unfrequently exhibits an iridescent play of colours.

It occurs in mass or crystallized. The primitive form of its crystals is a strait quadrangular prism, the bases of which are oblique parallelograms, and the angles $= 113^{\circ} : 7' : 48''$ and $66^{\circ} : 52' : 12''$. The chief varieties of crystallization that it is found to undergo are the following.

1. A thin oblique paralleliped bevelled unequally on all its four sides. When the crystal is short, the planes of its bases approach to the rhomb, but when it is long, they become lengthened oblique parallelograms; in either case the plane angles are alternately $126^{\circ} : 52' : 12''$ and $53^{\circ} : 7' : 48''$.

2. The long variety of the preceding, in which the parallelograms of the bases are converted into hexagons, whence the result will be a lengthened hexahedral table with equal opposite angles and bevelled unequally on all the six sides.

3. Another variety is produced by No. 1. being divided into two equal parts, by a plane passing parallel to the two longest sides, and these halves being half turned round upon each other: in consequence of this the planes at the bases will be hexagons, with one re-entering angle opposite to an equal salient one.

4. An octohedral prism with alternate broad and narrow sides, terminated by tetrahedral summits.

5. A strait hexahedral prism of which the bases are slightly convex. When the prism disappears the crystal passes into the next variety.

6. A spherical convex lens. These lenses are either solitary or set edge-wise, forming the cock's-comb gypsum, or arranged circularly like the petals of a flower, or adhering together in pairs by part of the surface near the extremity of the disk, thus forming a salient angle opposite to a re-entering one; when several of these are accumulated on each other, diminishing gradually in size, and the salient angle of the inferior pair fitting into the re-entering angle of the superior pair, an aggregate is produced resembling the head of an arrow; this variety is often found a foot or more in length.

The planes corresponding to the bases of the original prism are smooth, and more or less specular, the others are longitudinally striated and shining. The magnitude of the crystals varies from middle-sized to large. Its internal lustre is bright shining between vitreous and pearly.

The fracture of selenite is perfectly foliated either strait or curved: it is divisible in three directions, of which one parallel to the base of the original prism is very well determined, and the two other lateral divisions may be obtained by gently and judiciously striking a thin lamina with any hard body; the surfaces thus discovered are however much less shining than the former. The fragments are rhomboidal, specular on two surfaces, and striated on the four others. When in mass it sometimes presents coarse granular or testaceous distinct concretions. It is commonly transparent, but sometimes only translucent, and has then often a disagreeable odour when rubbed. It possesses a double refraction; is so soft as to be scratched by calcareous spar; is flexible in thin plates, but not elastic; is easily frangible, but not very brittle. Sp. gr. 2.26 to 2.32.

It is infusible in the focus of the most powerful lens, nor does it yield to a blow-pipe supplied with oxygen gas, if it is not laid on a charcoal support. When exposed to the com-

* Emmerling, Haüy, Brochant, Jameson, Kirwan.

mon blow-pipe it undergoes little alteration if the flame is directed to the surface of the laminæ, but if the interior blue flame is made to play on the edges of the laminæ, or the striated surfaces, it soon melts into an opaque white globe, probably in consequence of its acid being partly converted into sulphur. When dried as highly as possible without injuring its transparency it contains, according to Kirwan,

Lime	- - -	34
Sulphuric acid		48
Water	- - -	18

100

Selenite abounds at Mont Martre near Paris, at Shotover hill near Oxford, of singular beauty at the salt-mines in Upper Austria, also in Saxony, Spain, and elsewhere.

2 Subspecies. FIBROUS GYPSUM. *Gypse fibreuse*, Broch. *Fafriger Gips*, Wern.

Its colour is snow-white, yellowish, greyish, or reddish-white, flesh red and light hyacinth brown: several of these colours occasionally co-exist in the same specimen, forming stripes and bands. It occurs acicular and in mass, but never in very thick beds. Its internal lustre varies from glistening to bright shining, with a pearly lustre. Some varieties notwithstanding their fibrous texture are almost specular. Its fracture is parallel-fibrous either straight or curved, and sometimes almost passing into radiated; the fibres themselves vary from thread-shaped to broad and flattened. In the department of Aveyron is a remarkable variety of gypsum, consisting of the broad foliated or selenite, penetrated at right angles to its principal fracture by fibrous gypsum, hence it is foliated in one direction and fibrous in another.

Its fragments are long-splintery. It is semitransparent passing into semitranslucent; when polished it becomes iridescent: its hardness is for the most part somewhat inferior to the preceding subspecies: it is easily frangible and is brittle. Sp. gr. 2.3. It never effervesces with acids. It is affected by the blow-pipe, &c. in the same manner as the preceding.

3 Subspecies. GRANULARLY-FOLIATED GYPSUM OR ALABASTER. *Gypse lamelleux*, Broch. *Korniger gips*, Emmerl. *Blattriger gips*, Wern.

Its colour is snow-white, greyish, yellowish, or reddish white; flesh-red, blood-red, and brick-red; wax-yellow, smoky-grey and greyish black. Several of these colours are combined in veins, spots, and bands. It occurs massive and in blunt-edged fragments. It is translucent; its lustre is between pearly and vitreous, and varies

from shining to glistening. Its fracture is foliated, generally somewhat curved, and passing into radiated; its fragments are indeterminately angular and blunt-edged. It abounds in fine and coarse granular and prismatic distinct concretions; when fine-grained it often crumbles between the fingers like tender sandstone. In hardness it exceeds the preceding variety, but is easily frangible. Sp. gr. 2.27 to 2.31.

It generally effervesces more or less with acids on account of the carbonate of lime with which it is mixed. There is a considerable external resemblance between this and granular limestone, from which however it is at once distinguishable by its inferior hardness. It passes by insensible degrees into the next subspecies.

4 Subspecies. COMPACT GYPSUM OR ALABASTER. *Gypse compacte*, Broch. *Dichter gips*, Wern. and Emmerl.

Its colour is ash-grey, passing into smoky and yellowish-grey. It occurs in mass. Internally it is dull with a few glimmering particles. Its fracture is even, passing into splintery and very fine granular. Its fragments are indeterminately angular, blunt-edged. It is translucent on the edges, is soft and easily frangible, but not very brittle, has a dry but not a harsh feel. Sp. gr. 2.3. Like the preceding it commonly effervesces with acids.

5 Subspecies. EARTHY GYPSUM. *Gypse terreux*, Broch. *Gipserde*, Wern.

Its colour is yellowish-grey passing into yellowish-white, or snow-white. It is composed of pulverulent grains slightly adhering together: it is for the most part dull, but contains a few glimmering particles; has a harsh meagre feel, but is not gritty between the teeth; it stains the fingers, and is easily broken down into powder. When heated a little below redness it becomes of a dazzling white: it usually gives a slight effervescence with acids. It is of rare occurrence, and appears always to originate from depositions made from water that has flowed over a bed of gypsum.

II. FAMILY. Affords little or no water by distillation; does not become opaque and fall into powder at a temperature below a red heat.

6 Subspecies. ANHYDROUS SELENITE. *Chaux Sulfatée anhydre*, Haüy.

Its colour is greyish-white; it occurs in detached lamellæ or in slightly cohering foliated masses. It is divisible with equal ease and neatness in all directions, hence its primitive molecule is a cube. It is translucent, and possesses a considerable lustre. Its hardness is somewhat superior to that of calcareous spar; sp. gr. 2.96.

It requires a much larger quantity of water

for its solution than common felenite. Its component parts according to Vauquelin, are

Lime	- - - -	40
Sulphuric acid	-	60

100

It has hitherto been found only in the salt mines of the canton of Berne in Switzerland.

7 Subspecies. MURIACITE (of Poda.) *Soude muriatée gypsifère*. Haüy.

The colour of this is greyish white, greyish black, or reddish white. It occurs in loosely adhering rectangular plates, with bright specular surfaces; its primitive molecule is a cube. Its hardness is superior to that of common gypsum. It is weakly saline to the taste, it requires 4300 parts of water for its solution. It has been analyzed by Klaproth,^b and appears to consist essentially of

Gypsum	- - -	65
Muriated soda	-	35

100

It is found in the salt-pit of Halle in the Tyrol, and is called by the miners scaly gypsum (*schuppiger gypsstein*). It was first introduced to the notice of mineralogists by the Abbé Poda, who erroneously supposed it to consist of muriat of lime.

8 Subspecies. GRANULAR ANHYDROUS GYPSUM. *Chaux Sulfatée Quartzifère*. Haüy. *Pierre de Vulpino*. Bardiglio marble of the Statuaries.

Its colour is greyish white, veined with greyish blue; its fracture is fine-granular passing into splintery; its lustre is glimmering; its hardness is inferior to that of statuary marble, but it cannot be scratched by the nail. Sp. gr. 2.87.

It is moderately phosphorescent by heat, is very fusible before the blow-pipe, and effervesces strongly with acids. It consists according to Vauquelin, of

Sulphated lime	- - -	92
Silex	- - - -	8

100

It is found near Vulpino in the Bergamese, and is employed by statuaries for chimney-pieces, &c.

Concerning the three latter subspecies, which are supposed by Haüy to belong to the class of anhydrous gypsum, it will be necessary to say a few words. Of these the first (No. 6) is the only one that has been analyzed with sufficient

accuracy. It appears to have been taken in hand by Vauquelin himself, and therefore there is no reasonable ground for suspecting the exactness of the given analysis; we may therefore conclude it to be ascertained that there exists such a combination as sulphuric acid and lime, destitute of water of crystallization; and that this combination essentially differs from common gypsum in the cubical form of its molecules, in its superior hardness and greater specific gravity.

The gypsum in muriacite is supposed by Haüy to be anhydrous merely from its cubical molecule, and the large proportion of water required for its solution; yet we may infer that it contains water from the result of the Abbé Poda's analysis, however incorrect in other respects; he would hardly have stated it to contain lime, muriatic acid, and *water*, except he had actually procured some of this fluid from it by distillation. The Bardiglio marble is supposed to belong to the same family, first, because it is stated on the authority of Vauquelin to contain 92 per cent. of gypsum, and therefore from its specific gravity amounting to 2.87 it is inferred that this must be the anhydrous gypsum whose sp. gr. is 2.96, rather than the common, whose sp. gr. does not exceed 2.32. We are very much inclined however to disbelieve the reported analysis, not from any suspicion of the accuracy of Vauquelin himself, but because we are persuaded that many analyses made in his laboratory and by his pupils, are allowed very unjustly to pass current in the world under the name and authority of Vauquelin. This Bardiglio marble effervesces very vehemently with nitrous acid, and we are almost inclined to suspect that in the analysis *sulphat* of lime has been inadvertently mentioned instead of *carbonat* of lime. If this is the case the great specific gravity is also accounted for, that of common granular limestone being = 2.83, and the impure varieties of the same being still heavier.

There appear to be three very distinct formations of gypsum. The oldest belongs to the class of primitive mountains, and has hitherto been only met with in the vicinity of Bellinzona, among the Italian Alps. It forms alternate beds with gneiss, has a schistose texture, and abounds in mica. Gypsum of the second formation rests upon the oldest floetz limestone, and is disposed in beds alternating with swinstone, and occasionally with rock salt. The gypsum of this formation is mostly the compact

^b Analyt. Ess. I. p. 263.

and granularly foliated, it contains several substances imbedded in it, such as quartz, arragonite, boracite and sulphur, and most of the salt springs are found in this formation. The most recent gypsum rests upon the second sandstone formation, and alternates with indurated clay and sandstone, and is frequently covered with secondary floetz limestone; fibrous gypsum is chiefly characteristic of this formation, and it contains as well as the preceding the bones of quadrupeds, but scarcely any other organic remains.

Gypsum generally forms banks and hills of little elevation in plain countries, or at the mouth of large vallies. It abounds in the neighbourhood of Paris, at the foot of the Alps in Switzerland, Italy, and Tyrol; in Bavaria, Saxony, Thuringia, Poland and Spain; in

England, in Derbyshire, Yorkshire, and Nottinghamshire; in Pennsylvania in North America.

The uses of gypsum are very extensive; when it is sufficiently compact it is employed by the architect for columns and other ornaments, being easier to work than marble; it is also turned by the lathe into cups, basons, vases, and other similar articles. When exposed to a low red heat it parts with its water of crystallization, is converted to a fine powder called plaster of Paris, like meal, and this when beaten up with water to the consistence of paste, shortly after sets and becomes solid, hence it is largely used for taking casts of various magnitude, from a medal to a colossal statue, and enters into the composition of many cements. For further particulars relative to the chemical properties of this substance, see SULPHAT OF LIME.

H

HÆMATITE. See IRON, *Ores of.*

HAIR. The chemical composition of hair appears by the experiments of Mr. Hatchett to resemble very closely that of nail and horn. Boiling water extracts from hair a very small portion of gelatin, and the hair after drying is somewhat stiffer and more brittle than before. The chief constituent of hair appears to be organic, condensed albumen. (See HORN.)

Hair may be dyed permanently in several ways. A black or dark colour, which is generally desired, is given by many metallic solutions, particularly that of silver much weakened, but these are liable to corrode its substance, if not carefully used. Pallas^a relates that the women of Astracan dye their hair, while growing, of a fine glossy black, in the following way: twenty-five galls are first boiled in oil, then dried and powdered: to this is added, 3 drams of green vitriol, one dram of cream of tartar, and one dram of indigo, and the whole stirred up with a quart of water, to which is added a handful of the dyeing herb *henne*. The hair is anointed with this over night, care being taken not to blacken the skin, and is washed in the morning. This application gives a shining black which lasts several months.

HALBOPAL. See OPAL.

HARMATOME. See STAUROLITE.

HARTSHORN, Salt, Spirit, Oil, & Earth of.

Salt of Hartshorn is properly the carbonat of ammonia, prepared by the simple distillation of bone, or stag's horn, purified by rectification.

It is a tolerably pure carbonat of ammonia, but retaining a strong sub-empyreumatic scent of the animal oil, which is intimately mixed with it, and is apt to render it yellow. The spirit of hartshorn is this ammoniacal salt dissolved in alcohol, by the medium of distillation, and is a strong and powerful cordial and stimulant.

The *Oil of Hartshorn* is commonly dark-coloured and fetid, but may be rendered limpid and fragrant by rectification. It is then called *Dippel's Oil*. The *Earth of Hartshorn* is phosphat of lime. (See the articles HORN and BONE.)

HEAT. See CALORIC.

HEAVY-SPAR. *Baroselenite Kirw. Schwer-spath, Wern. Spath Pesant, Broch. Baryte Sulfatée, Haüy.*

Of this mineral there are the following subspecies.

1. **Subspecies. FOLIATED HEAVY-SPAR.** *Gerad-schaaliger and Krummschaaligen Schwer-spath, Wern.*

The principal colours of this substance are milk-white, greyish yellowish and reddish-white, yellowish-grey, smoky and pearl-grey, wine yellow, yellowish-brown, flesh-red, blood and liver-red, also very rarely greyish-black; greenish-grey, olive and oil-green; bluish-grey, smalt and indigo-blue.

It occurs crystallized, in mass, reniform, and globular.

Its primitive figure is a strait rhomboidal prism, the measure of whose angles is $101^{\circ} 30'$ and $78^{\circ} 30'$: and this is again divisible by planes

^a Travels in the Taurida.

passing through the diagonals of the bases, into four straight triangular prisms, with rectangular bases. The other varieties of crystallization that it presents are,

1. The octohedron, usually wedge-pointed, but sometimes regular.
2. The primitive figure with the obtuse solid angles, replaced by triangular planes.
3. A six sided table, sometimes elongated.
4. A four sided table, bevelled at the edges.
5. The same with the solid angles replaced by quadrilateral facets.
6. A compressed ten-sided prism, with dihedral summits.
7. The same as No. 5. with the lateral edges replaced by narrow quadrilateral planes.
8. An octohedral prism more or less compressed, and terminated by summits composed of seven or more faces.
9. Lenticular, either single or aggregated.

The planes of the crystals are smooth, and generally bright shining, with a pearly lustre. Internally it varies from bright shining to glistening, with a lustre between pearly and vitreous. Its fracture is either straight, or curved foliated, passing occasionally into splintery and radiated; the straight foliated presents straight, lamellar, wedge-shaped, distinct concretions, the curved foliated presents curved and thick lamellar distinct concretions. The crystallized varieties possess a double refraction, and are transparent, and semitransparent: the others are mostly translucent. Its hardness is between that of calcareous and fluor spars. It is easily frangible, but not particularly brittle. Sp. gr. 4.3 to 4.47.

When pure it does not effervesce with acids. It melts without addition before the blowpipe into a white enamel. Its component parts according to Withering, are

Barytes	-	-	67. 2
Sulphuric acid			32. 8

100. 0

The massive and globular varieties generally however contain a little sulphat of strontian, together with silica and iron.

It occurs usually in veins, seldom in beds, in rocks of almost every formation, from primitive to the newest floetz-trap: next to quartz and calcareous spar, it is the most abundant material of mineral veins, and particularly of those which contain galena and grey antimony.

2. Subspecies. COLUMNAR HEAVY SPAR. *Stangen-spath.* Wern.

Its colour is milk-white, yellowish, greyish, and greenish-white. It occurs always crystallized in needle-shaped rhomboidal prisms, which are columnarly aggregated, and intersect one another. It has a brilliant, pearly, and in some instances, almost semimetallic lustre: its longitudinal fracture is straight foliated: its fragments are rhomboidal: it is soft, easily frangible: sp. gr. 4.5.

It is found in metallic veins, in Saxony and Derbyshire, and is often mistaken for white lead ore; from which however it differs, in possessing less lustre, and inferior specific gravity.

3. Subspecies. BOLOGNIAN SPAR. *Bologneser spath.* Wern.

Its colour is smoky-grey, passing into ash and yellowish-grey. It occurs imperfectly lenticular, and in compressed pieces. Its lustre internally varies from shining to glistening and resinous. Its fracture is radiated, passing into obscurely foliated. Its fragments are wedge-shaped, or indeterminately angular. It sometimes occurs in large-grained distinct concretions. It is strongly translucent. When rubbed, it gives out a fetid sulphureous odour. In other characters it agrees with subspecies 1.

It is found imbedded in clay and marl at Monte Paterno, near Bologna in Italy. For its phosphorescent quality, see PHOSPHORIC SPAR.

4. Subspecies. GRANULAR HEAVY SPAR. *Körniger Schwespath.* Wern.

Its colour is snow-white, milk-white, and smoky-grey. It occurs always in mass. Its lustre is glistening and pearly. Its fracture is small and fine foliated, passing into splintery. Its fragments are indeterminately angular and blunt-edged. It presents small, fine-grained distinct concretions. It is feebly translucent, is moderately hard, and easily frangible. Sp. gr. 4.38.

It undergoes no loss of weight by ignition: its component parts according to an analysis by Klaproth, are,

Barytes	-	-	60	} 90 Sulphat of barytes
Sulphuric acid			30	
Silex	-	-	10	
			100	

It occurs in beds with galena, at Peggau in Stiria, in the vicinity of Freyberg, and at Schlangenberg in Siberia with malachite and native copper.

In its external appearance it singularly resembles the purest granular limestones, but may be distinguished independently of chemical cha-

acters, by its inferior lustre, and superior specific gravity.

5. Subspecies. COMPACT HEAVY SPAR. *Caruk* of the Derbyshire miners. *Dichter Schwerspath*, Wern.

Its colour is yellowish-white, passing into greyish-white. It occurs in mass, and in kidney shaped and hemispherical nodules. It is either dull or has a glimmering lustre. When dull, its fracture is coarse earthy; when glimmering, its fracture is small radiated, passing into granularly foliated. Its fragments are indeterminately angular, and blunt-edged. It often presents thick, curved, lamellar, distinct concretions. It is opaque; sometimes translucent on the edges; has a meagre feel, is soft, and easily frangible. It is found in metalliferous veins in Saxony, Savoy, Derbyshire, &c.

6. Subspecies. EARTHY HEAVY SPAR.—*Schwerspath erde*, Wern.

Its colour is reddish or yellowish-white. It occurs in mass, and consists of glimmering, and generally coarse earthy particles. It does not stain the fingers: it is either pulverulent or friable; has a meagre and somewhat coarse, rough feel. It occupies cavities in veins of heavy spar, and appears to be the dull variety of the preceding subspecies, in a somewhat less indurated state. It is found near Freyberg in Saxony, and in the mining districts of Staffordshire and Derbyshire in England.

HELIOTROPE. *Heliotrop*, Wern.

Its principal colour is deep leek or celandine green, passing into mountain-green, and occasionally into dark olive: it is also dotted with opaque spots of a blood or scarlet red, or ochre yellow. It occurs massive; in angular or rolled pieces. Its internal lustre is glistening, nearly resinous: its fracture is large and imperfectly conchoidal, passing into scaly: its fragments are indeterminately angular, and sharp-edged. It is commonly translucent on the edges, sometimes translucent.

It is hard, and easily frangible. Sp. gr. 2.62 to 2.7.

It is infusible before the blowpipe without addition.

It is found in rocks belonging to the floetztrap formation, and appears to be the connecting link between chalcedony and jasper; according to Werner, it is an intimate mixture of chalcedony and green earth. It is found in Bucharía, Persia and Siberia in Asia; in Iceland, and Upper Saxony in Europe. From the beauty of its colour, and its hardness, it is in considerable request among lapidaries. That which is

the most translucent, and has the greatest number of red spots, is most esteemed: it is known in commerce by the name of oriental or blood-jasper.

HEPAR

HEPATULE

} See SULPHURET.

HEPATIC AIR. See SULPHURETTED HYDROGEN.

HOLZOPAL. See OPAL.

HOLZSTEIN. See WOOD petrefied.

HOMBERG'S PHOSPHORUS is the common PHOSPHORUS, (which see.)

HONEY. *Miel*, Fr. *Der Honig*, Germ.

Honey, the most antiently used and one of the most grateful of all the saccharine juices, is a natural compound of a considerable portion of sugar intimately mixed with several other substances that give it its slimy consistence, its peculiar colour, smell, and flavour, together with a small portion of natural acid.

Honey is found differing much in consistence and colour, being sometimes nearly as stiff as soft suet, sometimes as thin as a balsam, and of various shades of yellow, gold-colour, brown, and sometimes nearly white. The goodness of honey for culinary purposes is chiefly determined by the delicacy of flavour, but the comparative quantities of sugar and other chemical differences have not been much examined.

When honey is gently warmed over a slow fire it liquefies and a thick scum rises to the top, which when removed leaves the honey somewhat purer than before, and makes the *despumated* or *clarified honey* used in pharmacy. If the honey is naturally thick it should be previously diluted with a little water. When clarified honey is slowly evaporated it becomes a thick tenacious mass, loses its delicacy of flavour, and acquires one somewhat disagreeable, becomes brown and foul, and can never by this means be made to yield crystals of pure sugar. The stronger the heat, and the browner and higher-flavoured it becomes. Whilst evaporating, a vapour rises, which takes fire at the approach of a candle and fills the house with a very strong and penetrating smell. Neuman obtained from 32 ounces of honey by distillation *per se* on a slow fire about 24 ounces of an acid watery liquor mixed with a brown oil. The residue strongly heated gave a coal difficult of incineration.

Owing to the abundant quantity both of sugar and of extract or mucilage in honey, it very readily enters into the vinous fermentation and yields a very strong wine, called *mead*, which possesses much of a honey flavour that lessens by

keeping, and a very strong body. Neuman obtained a mead from 36 ounces of honey diluted with 4 quarts of warm water and fermented with yeast, which by distillation and rectification gave 8 ounces of strong alcohol.

The most interesting experiments on honey are those which have been made with a view of purifying it, and separating the truly saccharine part from every other. For the purification from its peculiar flavour which is offensive to some palates, and from the yellow colour, mere despumation and the other usual modes of clarification will not answer; Mr. Lowitz has indeed found that when diluted with water and passed through fresh burnt charcoal * it lost its smell and colour, but on again inspissating it by a very gentle fire, it soon acquired its former brown colour and did not shew any tendency to crystallization. By long keeping, this honey spontaneously separated into a mass of white concrete granulated matter entangled in a viscid slime. In this state it resembled the white concrete natural honey often met with. This concrete matter was dissolved by hot alcohol, which left the other part nearly untouched. On letting the alcoholic solution stand at rest for some days a number of spherical knobs began slowly to separate, which gradually increased, forming a snow-white crust, which on being removed and dried would bear cutting with a knife into thin slices. This appeared to be the saccharine part of the honey in a considerable state of purity, but still so intimately united with some other ingredient as not to be crystallizable, as pure sugar is, but only to separate in these cauliflower-like knobs, which examined by the microscope, appeared composed of small thin longish crystals.

Mr. Lowitz also gives as characteristic differences between this white sugar of honey and common white sugar, that the former is rendered brown by lime-water, and with lime in substance and a little water a strong effervescence takes place, and the mixture becomes black, thick, and nauseous, which, clarified by charcoal and evaporated nearly to dryness, leaves a bitter yellow extract. None of these appearances take place with lime and common white sugar, neither discolouration nor decomposition being produced. The caustic fixed alkalies also produce a similar effect upon the sugar of honey, but not upon common sugar. (*See the article Sugar.*) The saccharine part of honey therefore appears most intimately combined with the extractive, and it appears probable that no direct attempts to procure pure sugar from honey will

succeed, except by going through the whole process by which sugar is obtained from the cane juice. In this latter way, and with the use of claying, Neuman asserts that he has obtained a good sugar from honey resembling the fine moist sugars prepared in this way, but still not in the form of hard well-defined crystals.

Honey is often adulterated with flour, which may be detected by diffusing it in blood-warm water, by which all the honey will be dissolved and the flour remain nearly unaltered, and a subsequent boiling of the residue in the water will convert the flour into thick paste.

Honey is used only for culinary and medicinal purposes. The distilled acid spirit was formerly thought, but quite erroneously, to be a solvent for gold and silver. The same *honey-water* has the reputation of making the hair grow, and with as little foundation.

HONEYSTONE. } See MELLITE.
HONIGSTEIN. }
HORN.

Under the general article of horn may be included (chemically considered) a great variety of tough, somewhat flexible, semitransparent organs intended by nature for defence or covering. Of this kind are the hollow horns of the ox, goat, ram, and some other animals, the hoof, the horny claw and nail, and the horny scale of certain insects and animals, chiefly cold-blooded, such as the *shell* (so called) of the tortoise. All these resemble each other very closely in chemical character, and differ considerably from some of the harder and bony defences of some animals, such as the stag's-horn, ivory, and the hard tusks of the sea-cow, and many others.

Horn (used in the above general sense) has various degrees of hardness, but is always in some degree tough and flexible, even in the cold, so that however dried, it cannot be bruised to powder as bone can. It is also distinguished from bone very remarkably, in being softened very completely by heat, either naked, or through the medium of water, so as then to be readily bent, moulded, and made to adhere by pressure to other pieces of horn in the same state.

No such change takes place with bone.

The valuable experiments of Mr. Hatchett, with those of preceeding chemists, have also shewn a most decided chemical difference between horn and bone. When bone is boiled with water in an open vessel, (as mentioned under that article) a large quantity of *gelatin* is extracted, and the insoluble residue consists

* Phil. Transf. vol. 90. p. 372.

of the earth of bone, together with the albuminous cartilage, so that the texture remains unbroken. On the other hand, the different species of horn boiled with water even for many days, give to it but very little gelatin, or any other principle, but of this small portion of gelatin, the softer and more flexible horns give the most. The horn itself during the digestion, is softened considerably by the hot water, but on being taken out and dried, it becomes more brittle than at first, and in proportion to the loss of gelatin. Bone therefore contains much gelatin, and horn scarcely any.

Another difference appears after the utmost action of fire on each. When bone is burnt, a number of substances are procured, as described under that article, and the last residue is an earthy salt, chiefly phosphat of lime, amounting on an average to from half to one third of the entire weight of the bone. When horn is treated in the same way, the volatile products are indeed the same, or nearly so, but instead of a large earthy residue, scarcely any earth, or any other combustible matter remains. Bone therefore contains much phosphat of lime, but horn hardly any.

But the substance which they possess in common is that condensed tough matter, insoluble in water and weak acids, which Mr. Hatchett has so satisfactorily shewn to resemble albumen in all essential properties, and which in bone forms the original organic cartilage on which the earth is deposited during the growth of the animal, and in horn forms almost the whole substance.

The peculiar properties that identify this substance with the albumen of eggs, have been already fully described under the articles *Bone*, *Albumen*, and *Gelatin*, and need not be here repeated.

Horn therefore seems to consist in by far the largest proportion of condensed albumen, combined however with a small and varying portion of gelatin, which modifies its texture and flexibility, and also with a small portion of phosphat of lime.

It has been mentioned that boiling water in open vessels had hardly any action on horn, but when confined in a digester, horn as well as bone is totally soluble, because water assisted by the strong heat of a digester, will dissolve condensed albumen as well as gelatin. This method therefore is not sufficiently distinctive for chemical analysis.

The fixed alkalis readily and totally dissolve horn into a yellow saponaceous liquor.

The products obtainable from horn and bone of all kinds by distillation per se, were early attended to by chemists, as it is from these substances that a variety of valuable ammoniacal salts and preparations are obtained.

The products from bone and horn by fire are very similar, as it is only the soft parts, such as gelatin and albumen, that are decomposed in the process, the earthy phosphat remaining inert without adding to or modifying the volatile products. These latter are a weak ammoniacal phlegm or water, on the first impression of the fire, to which succeeds an oil thin and limpid at first, but afterwards brown and foul, and at last of a pitchy colour and consistence, and an extremely fetid empyreumatic smell. During the whole of the distillation, carbonat of ammonia comes over, partly dissolved in all the liquid products, and partly concreting on the sides of the receiver in crystalline plates. A second distillation with regulated heat is used to procure the ammonia purer; but it can hardly ever be totally freed by this means from the volatile oil; so that, though limpid and gratefully ammoniacal, the alkaline liquor or salt thus obtained, always retains somewhat of the peculiar smell of the oil, as must be observed by every one who compares the scent of common *spirit of hartshorn* with that of the pure carbonat of ammonia or *sal volatile*, which is prepared in a different way, and from other materials.

But horn (properly speaking) is seldom employed for the purpose of distillation, being too valuable as an article of manufacture to be thus sacrificed. The only horn ever used thus is the *stag's* or *hartshorn*, which as above mentioned, partakes much more of the nature of bone, is not flexible like ox and other horn; when in shavings, readily dissolves by boiling water into a pure nutritious gelly, entangling the phosphat of lime along with it, which makes it slightly opaque. Stag's horn therefore is somewhat intermediate in properties between bone and true horn.

Horn and tortoise shell being applied to a number of mechanical purposes, must be cut, bent and shaped in an infinite variety of ways. This is done in most instances by the assistance of heat applied either dry, with warmed irons or burning charcoal, or by softening the horn in boiling water, and sometimes with the assistance of a weak alkaline liquor. When thus softened, one part may be made to adhere to another by mere pressure as firmly as the undivided substance. Thus for example, to make the horn

ring that surrounds a common opera glass, a flat piece of horn is cut out of the requisite shape, the ends intended to join are thinned down by a file, the piece is then put into boiling water till sufficiently supple, and is then rolled round a warmed iron cylinder, and held in that position by a vice, so that the ends overlap each other. Another piece of iron heated and grooved is then laid upon the seam of the joined ends, and pressed upon the cylinder, and confined there by iron wire; and the heat of the two partially melts that portion of the horn, and cements the ends so completely, that no seam or joining can be observed when cold.

In a similar manner, two pieces of tortoise-shell may be joined together, by first neatly shaping with a file the parts that are to be united, then tying a thick paper doubled in several folds over the joining, and pressing the whole together with a hot iron instrument like curling irons, heated just sufficiently that the shell when warmed by it, will begin to bend by its own weight. When cold, the joining is perfect, and without seam. Too great heat would make the shell rise in white opaque blisters, and spoil its beauty.

Horn is made to imitate tortoise-shell, in the following manner:^a make a paste with two parts of quick-lime, one of litharge, and a little soap-makers' ley, or solution of caustic potash; apply it skilfully on a thin plate of horn in a way that will best imitate the natural spots of the tortoise-shell, leaving the light parts untouched; let this paste dry on, then brush it off, and the horn will be permanently stained. The effect is much improved by laying beneath it when used, a piece of brass leaf. This staining may be varied at pleasure, by substituting other coloured substances to the litharge.

HORNBLENDE. *Amphibole*, Haüy.

Of this mineral there are the following species.

I. **BASALTIC HORNBLENDE.** *Basaltische Hornblende*, Wern.

Its colour is pure black, greyish or greenish-black: by decomposition it becomes brownish-black and acquires a superficial varying tint of colour. It occurs almost always in single imbedded crystals. Its primitive form is an oblique prism with rhomboidal bases, the angles of which are respectively $122^{\circ} : 56'$ and $57^{\circ} : 4'$. The other varieties of crystallization that it offers are,

1. A six-sided prism with trihedral rhomboidal summits.

2. The same prism terminated at one extremity by a tetrahedral and at the other by a dihedral summit.

3. The same as No. 1, except that one of the summits is dihedral.

4. The same as No. 2, except that four small rhomboidal facets are added to the dihedral summit.

5. A six-sided prism terminated at each extremity by six facets, but dissimilar.

The crystals are small and middle-sized. The surface is smooth and shining except where it happens to be covered by a thin ochery crust. Its longitudinal fracture is perfectly strait foliated; the cross fracture is uneven and small conchoidal: the lustre of the principal fracture is bright-shining, that of the other is glimmering and vitreous. The fragments are indeterminately angular approaching to rhomboidal. It is opaque, gives a greyish white streak, is moderately hard and easily frangible; it exhales an argillaceous odour when breathed upon. Sp. gr. 3.15 to 3.3.

Before the blowpipe it melts, with more difficulty than common hornblende, into a brownish-black glass. Its component parts, according to Bergman, are

Silex	- - -	58
Alumine	- - -	27
Iron	- - -	9
Lime	- - -	4
Magnesia	- - -	1
		99

It is found imbedded in basalt and wakke and in lava: being for the most part less decomposable than basalt, many fine crystals are procured from the clay which is found at the foot of most basaltic rocks. The crystals met with in lava not unfrequently affect the magnet. It is found in Saxony, Bohemia, Italy, Scotland, &c.

II. **COMMON HORNBLENDE.** *Gemeiner Hornblende*, Wern.

Its colour is greenish or reddish black, greyish black or greenish-grey. It occurs in mass, disseminated and crystallized: the crystals are imbedded and intersect one another, so that they cannot be very accurately determined, but they seem to be slight modifications of the primitive figure as described under the preceding subspecies. Internally it is more or less brightly shining, with a pearly lustre. The fracture is strait rarely curved-foliated, passing into broad.

radiated: the fractured surface is generally longitudinally striated. The fragments are indeterminate angular blunt-edged, passing into rhomboidal. It presents granular distinct concretions. The lighter coloured varieties are usually transparent on the edges. It gives a greenish grey streak, is moderately hard, tough and difficultly frangible. When moistened it gives out a strong argillaceous odour. Sp. gr. 3.6 to 3.8.

It melts easily before the blowpipe into a greyish black glass. The following are the results of its analysis.

	Kirw.	Wiegleb.	Hermann.
Silex - - -	37	48.83	37.
Alumine - -	22	0	27.
Magnesia - -	16.	17.5	3.
Lime - - -	2.	16.66	5.
Oxyd of iron	23.	17.5	25.
	100.	100.49	97.

Hornblende forms an essential constituent part of syenite and primitive greenstone, also of transition and floetz-greenstone, and enters accidentally into granite, gneiss, micaceous schistus and granular limestone. It forms also entire beds which generally inclose magnetic iron. When in mass it forms an excellent flux for iron ores, and is largely employed in Sweden for this purpose.

III. LABRADOR HORNBLENDE. *Labradorische Hornblende*, Wern.

Its colour is brownish-black, greenish-black, copper-red, tombac-brown and greyish-black. It occurs in mass, disseminated and in rolled pieces. It varies from glimmering to shining, and has a semi-metallic lustre. Its fracture is usually curved foliated; its fragments indeterminate angular tending to rhomboidal. It presents lamellar distinct concretions; is opaque, moderately hard, and not difficultly frangible. Sp. gr. 3.38.

It is found in the Isle of St. Paul on the coast of Labrador.

IV. HORNBLENDE SLATE. *Hornblende schiefer*, Wern.

Its colour is between greenish and reddish-black. It occurs in mass forming entire beds. Its lustre approaches to pearly and varies between shining and glistening. Its fracture in the great is flaty, in the small is confusedly radiated. The fragments are generally tabular. It gives a greenish-grey streak, is opaque, moderately hard, not very frangible. It is often mixed with quartz, in which case its hardness is increased, also with felspar and mica.

It forms thick beds in primitive and transition rocks, especially in argillite, gneiss, and micaceous schistus.

HORNERZ. See SILVER, Ores of.

HORNSTONE. Of this mineral there are two subspecies.

I. SPLINTERY HORNSTONE OR CHERT. *Splittiger Hornstein*, Wern.

Its colour is usually grey, such as bluish, greenish, yellowish, smoky and pearl-grey, blackish-grey and greyish-black; it is also found flesh red, blood and liver red, olive green and mountain green. It occurs in mass and globular, and occasionally impressed by pyramids of calcareous spar. Its fracture is splintery, often fine splintery and with a tendency to conchoidal. It possesses no lustre when pure, but when mixed with quartz it becomes glimmering: its fragments are indeterminate angular, more or less sharp edged. When in mass its texture is uniform, the globular variety presents concentric lamellar distinct concretions. It is more or less translucent. It is hard, tough, moderately heavy and difficultly frangible. Before the blowpipe it becomes opaque, but is infusible *per se*.

II. CONCHOIDAL HORNSTONE. *Muschliger Hornstein*, Wern.

This differs from the preceding in the following particulars. It occurs only in mass, its colours are for the most part lighter, it is translucent only at the edges; its fracture is perfectly conchoidal; it is not so tough and therefore more easily frangible than the splintery variety.

There appear to be at least two distinct formations of hornstone, independent of hornstone PORPHYRY, which is ranked among the primitive mountains; of these the eldest occurs in transition mountains of argillite and greenstone, and appears to pass into quartz on one side and into hone slate (*wetzschiefer*) on the other; it forms veins and sometimes beds, and is mixed not unfrequently with iron or copper pyrites. The more recent hornstone occurs in secondary floetz limestone, with the strata of which it alternates as flint does with chalk. This hornstone it is which is known to English miners by the name of chert; its colour is greyish-white or greyish-black; by calcination it becomes milk white; it passes not into quartz but into chalcedony.

All those kinds of hornstone that become white by calcination form an excellent material for the better kinds of pottery. The best millstone called French bur is cellular splintery hornstone.

HYACINTH. See ZIRCON.

HYACINTH OF VESUVIUS. See VESUVIAN.

HYALITE. See THUMERSTEIN.

HYDRAT. This term has been applied by some late chemists, particularly by Proust, to express the chemical union of water with any substance and especially with some metallic oxyds. Thus the *hydrat of copper* is a blue-green oxyd of this metal, which differs from the brown oxyd only (as appears) in containing a large quantity of water, which a low red heat will expel.

HYDROGEN GAS, or *Inflammable Air*. *Wasserstoff Gas*, Germ.

Scarcely any substance has so much engaged the attention of modern chemists, and is so intimately concerned in the controversy between the supporters of the phlogistic and antiphlogistic theory of chemistry, as inflammable air in its various modifications. The precise date of the discovery of this gas is not certainly known, but it is unquestionably owing chiefly to the valuable researches of Mr. Cavendish that the production of water and the combustion of inflammable air have been proved to be constantly concomitant, and the numerous experiments of Dr. Priestley have had an equal share in first explaining its nature and properties.

Till the exact nature of this gas was explained by late researches, much confusion arose from a want of proper distinction between the true simple inflammable air or *hydrogen*, as it is called in modern nomenclature, and the various modifications of hydrogen holding carbon and other substances in solution, and also that other inflammable air (discovered by Dr. Priestley and explained by Mr. Cruikshank) which consists simply of carbon in a low state of oxygenation, already described under the article CARBONOUS OXYD. A due attention to these sources of error will enable us to reconcile many of the apparent contradictions that appear on this subject in the relations of Priestley, Lavoisier, Kirwan, and other eminent chemists.

Referring to the articles of PHLOGISTON and WATER the exact details of the experiments by which the leading property of *hydrogen*, that is (as its name implies) the *generator of water*, appears to be fully established, we shall here merely give the principal characters of this important gas.

Hydrogen gas is obtained in a state of considerable purity only by means of metals, and with particular ease and convenience from iron and zinc, either by the united action of the muriatic or sulphuric acid and water, or simply by

water coming in contact with these metals when strongly heated. But besides these sources, almost every inflammable vegetable and animal substance contains abundance of hydrogen, such as oil, alcohol, &c. &c. which is readily given out by heat, by electricity, and in a number of other modes of decomposition, and when burning in the air constitutes the *flame* which these substances produce on ignition. Therefore the character of *generator of flame* is highly characteristic of this gas, though by no means so exclusively as that of generating water, for phosphorus, oxyd of carbon, and a few other substances will produce flame on ignition, but no other known body but hydrogen will produce water. But generally speaking, the presence of flame is sufficient to suspect the presence of hydrogen.

To procure this gas, for experiment, take any quantity of malleable iron, such as iron turnings or clean nails, put them in a bottle with a bent tube, add to them some sulphuric acid diluted with about ten times its bulk of warm water, or muriatic acid less dilute, and almost immediately the action of the diluted acid will be seen by a number of minute bubbles detaching themselves from the surface of the metal, and rising rapidly to the top of the liquor. These bubbles are hydrogen gas, the first portions of which should be allowed to escape, being mixed with the air of the vessel, after which it may be collected in proper vessels over water or mercury for use. By keeping up a very moderate warmth, and occasionally adding more acid as the former portion becomes saturated, the same materials will continue giving out the gas for a great length of time. After saturation the liquor is a dilute sulphat or muriat of iron, according to the acid employed. It is of use to shake the bottle occasionally to detach a crust of oxyd of iron, which is apt to form on the surface of the metal when the sulphuric acid is used and impedes the further action of the acid. The precise degree of dilution of the acid is of little consequence. The explanation of this process according to the antiphlogistic system is, that the iron first decomposes part of the water, unites with its oxygen and becomes an oxyd of iron, whilst the hydrogen, the other constituent of the water, flies off in the form of gas: and the oxyd of iron then dissolves in the acid. So that the solution is properly a sulphated or muriated *oxyd of iron*. If it be asked what it is that suddenly determines or impels the iron to decompose the water, it can only (as far as our present know-

ledge reaches) be referred to that frequent but paradoxical explanation of an affinity beginning to act before one of the substances that are the subjects of that affinity is fully formed; that is to say, in the present instance, it is supposed to be the affinity between the sulphuric or muriatic acid and the *oxyd of iron* that causes the *metallic iron* to convert itself into an oxyd, by the medium of the decomposed water.

Hydrogen gas may also be procured in great abundance and with much more ease and rapidity by substituting zinc for iron in the above manner. The sulphuric or muriatic acid employed will bear full as much dilution. The zinc need not be minutely divided, no more being required than to form it into small lumps by pouring it when melted into cold water. The hydrogen gas begins to rise copiously the moment the zinc touches the acid, and more rapidly with the muriatic than the sulphuric.

Another method of procuring hydrogen gas in great abundance and purity is by sending the steam of boiling water over red hot iron confined in a tube of earth or iron. On account of the brittleness and porosity of earthen tubes those of iron are preferred. A portion of a gun-barrel open at each end is generally employed. This is long enough to be thrust through the middle of a furnace, and to project some inches out of it at each end. (*See in the Appendix the article HYDROGEN, Apparatus for.*) The centre of the barrel is filled with iron wire, or better with iron *turnings*, and heated red-hot. When hot, the vapour of boiling water is sent through them from a small retort half full of water, heated by a lamp and luted to one end of the barrel, and in its passage it is decomposed by the multiplied contact of the surface of the red-hot iron; and a copious stream of hydrogen gas issues out through the other end of the barrel, the bore of which is lessened by luting to it a narrow curved tube, which conveys the gas to the vessels appointed to receive it. The iron *turnings* after this operation are found to retain their shape, but to be converted totally or partially, into a brittle dusky lead-coloured glossy oxyd, which readily crumbles down under the finger. The inner surface of the barrel is also changed in the same manner to a small depth, and therefore hydrogen would be procured simply by sending the steam through the clean hot barrel as long as any of the surface remained in the metallic state. By frequent use, the barrel becomes corroded quite through, but if the inside is not scraped it will last a considerable

time. The outside also should be coated thinly with clay to prevent it from scaling when in the fire.

In this case as in the former, the hydrogen is produced and the metal oxydated by the decomposed water, and the increased heat is the circumstance which determines the first decomposition.

This decomposition of water by iron will take place even in the common temperature simply by moistening iron filings and keeping them in this state for a considerable length of time. The oxyd produced in this instance however, if the process is carried on in the open air, is generally united with a portion of carbonic acid.

Zinc when red-hot will decompose water in the same way as iron, but the process is not so easily managed on account of the fusion of the zinc which prevents that extensive surface for action which the iron *turnings* present.

Hydrogen gas has certain differences in some of its sensible properties, according to the way in which it is procured. When obtained from iron or zinc by means of the acids it has always a peculiar and fetid smell, and as Dr. Priestley has observed, if the production be very rapid, the gas from iron deposits an ochery film on water over which it stands for some time, and that from zinc deposits a white film. It is also in general heavier when obtained by means of the acids, than simply by passing water over hot iron, and in the latter case it has much less smell. On the whole however its *chemical* properties, in whatever of these ways it is obtained, if not mixed with atmospherical air, are sufficiently uniform to be described in common.

Hydrogen gas is an invisible elastic air uncondensable by any known cold, and is the only form in which pure hydrogen has ever been exhibited. Its specific gravity, as just mentioned, varies considerably according to the mode in which it has been procured. In general when pure it is from six to ten or even twelve times lighter than common air, so that eight times may be taken as a general average. It is therefore by far the lightest of all the gaseous fluids.

The levity of hydrogen is shewn in an entertaining manner by filling a bladder with it, either pure or even largely mixed with common air, fixing the bowl of a tobacco-pipe to the orifice of the bladder, dipping the bowl in soaped water, and by squeezing the bladder thus blowing soap bubbles of hydrogen, imitating balloons, which as soon as they are set at liberty rise

rapidly to the ceiling of the room and burst by striking against it.

It is incapable, of itself, of supporting combustion for a moment, a lighted taper dipped in it being immediately extinguished. But when pure hydrogen is put in contact with common air or still more with oxygen, and the surface of contact touched with a lighted taper or a red-hot iron, it immediately kindles at this place with a slight snapping noise, and burns with a faint blueish-white flame without any smoke and scarcely visible in the day time, and continues to burn gradually as long as the contact of air is continued, till the whole is consumed. This is amusingly shewn by filling a long-necked retort or long tube with pure hydrogen, placing it with the open end downwards (by which the gas on account of its levity is prevented from escaping) and kindling it with a taper. A ring of faint blue flame immediately appears at the open mouth, and continues slowly to travel up the tube till the whole is burnt out. If during the combustion the tube is suddenly turned up, the remaining hydrogen rises through the ring of flame, forming a large and sudden flash, and is immediately exhausted.

The combustion of pure hydrogen therefore is perfectly tranquil and progressive through the mass following the progressive contact of air, but if it be previously mixed with common air (or still more strikingly with oxygen) and agitated, and a lighted taper then applied, the whole takes fire instantly and burns with a large blue flash attended with a pretty violent explosion relatively to the quantity of materials. The electric spark kindles this mixture as well as a lighted body. It is on account of this property of sudden combustion with explosion that care should be taken not to kindle any portion of a large quantity of hydrogen, through however small an orifice, before the operator is sure of the purity of the gas within, for if it be mixed with any sensible quantity of oxygen, the flame instantly communicates to the whole mass, and a dangerous explosion might ensue. The force and danger of explosion is of course regulated (other things being the same) by the degree in which the gas is confined by the vessel in which it is made. Thus a common phial, holding half a pint of a mixture of hydrogen and common air in due proportions, will not burst by being kindled at the mouth, much of the force spending itself at the open orifice; and even, if the phial is stout, the same quantity of hydrogen and oxygen will

hardly burst by the explosion, though as loud as that of a common gun; whereas a very few inches of the same mixture confined in a very thick and close glass tube and fired by the electric spark, will often shiver it to pieces.

The proportion of oxygen required for the perfect combustion of hydrogen, is about one part in bulk of oxygen to two and a half of hydrogen, supposing each to be pure, or more accurately 85 parts *by weight* of oxygen to 15 of hydrogen. If common air be used, the proportions acquired for complete combustion are about 6, in bulk, of common air, to 2 of hydrogen. After explosion the bulk of the whole is reduced to about 5 parts, and is chiefly the azotic residue of the common air, which appears to be quite passive in this operation.

The great circumstances which distinguish the combustion of hydrogen whether slowly or by sudden explosion, are the total destruction of the two gases, relatively to their gaseous form, the entire absence of all visible vapour or smoke, and especially the production of a quantity of moisture, which precipitates in the form of a thick dew on the sides of the vessel wherein the combustion is carried on, and soon collects in sufficient quantity to trickle down in evident drops that continue as long as the process is going on. These drops when collected and examined by every chemical test are found to be, when the gases are as pure as possible, nothing but water.

The particulars of many most laborious and accurate experiments that prove this important fact, with the circumstances under which apparently contradictory results have been obtained, will be further mentioned under the article WATER.

Inflammable air proves almost instantly fatal to small animals introduced in it, as was ascertained by the experiments of Dr. Priestley. Scheele however found that he could respire the same quantity of this air in and out of a bladder alternately for several times, without material inconvenience. Many other experiments of Fontana^{*} on this subject prove, that this is owing to the great dilution which it undergoes in the latter case, by mixing with the large quantity of common air always present in the lungs; whereas when a small animal is immersed in an atmosphere of hydrogen, the air in its lungs makes no sensible proportion to the hydrogen. Both these were proved by examining each air by nitrous gas, which does not in the least diminish in bulk with hydrogen,

^{*} Phil. Transf. vol. 69.

but largely in common air on account of its oxygen. Pure hydrogen therefore does not appear positively noxious as the carburetted hydrogen, but only negatively so, as not containing any gas fit for respiration. Fontana expresses the feeling of a peculiar and extremely light and pleasurable sensation on the first inspiration of hydrogen, but by rashly persevering in repeatedly breathing it, vertigo, swooning, and dangerous oppression of the lungs come on.

Hydrogen is not sensibly altered by being kept at rest over water; nor is it readily absorbed by it, but by agitation Dr. Priestley caused water to take up about a thirteenth of its bulk, which was again expelled by heat unaltered. Pressure combined with agitation will cause a much greater absorption. Mr. W. Henry however gives the quantity of pure hydrogen absorbable by 100 cubic inches of water at the heat of 60° . by mere agitation and common pressure to be only 1.53 or about $\frac{1}{65}$.^b

One of the most striking properties which hydrogen exhibits is that of reducing metallic oxyds to the reguline or nearly reguline state. This is effected by the union of the hydrogen with the oxygen of the metallic oxyd, in consequence of which the hydrogen loses its gaseous form, and with the oxygen produces water. The metallic reduction by hydrogen appears to have been first noticed by Dr. Priestley, but the consequent production of water in these cases was suggested by the most important researches of Mr. Cavendish on the union of hydrogen and oxygen.

The first direct experiment on metallic reduction by hydrogen made by Dr. Priestley, arose out of the singular fact, also remarked by him, of the blackening of flint-glass tubes simply by being heated red-hot when containing hydrogen gas. Dr. P. found this to happen invariably with *flint-glass* under every variety of circumstances, but not with *green-glass*, and as the striking difference between the two is that the former contains oxyd of lead but not the latter, it was concluded with reason that the blackness was owing to the reduction of that metal.

This fact led to the following beautiful set of experiments:^c Some minium was put on an earthen support (a bit of crucible) and inclosed in a thin glass receiver filled with hydrogen gas standing over water. The rays from a lens were transmitted through a receiver (applied with caution) and concentrated on the minium so as to heat it red-hot. It then soon became

black and ran in the form of metallic lead, at the same time that the gas diminished rapidly, as was shewn by the rapid rise of the water within the receiver. Several of the other metallic oxyds heated in the same way diminished the quantity of hydrogen and were themselves reduced to or towards the metallic state. The oxyds of tin, bismuth and silver succeeded very well; copper, iron and cobalt, imperfectly. The copper in this instance was brittle, but became perfect copper when again fused with borax. The essential circumstance of the formation of water in these instances was not at first noticed, the actual quantity being very small and mingling with the mass of water with which the gas was confined. But on repeating the experiment over mercury some water was always detected, which was more than could well be accounted for from the accidental moisture of the metallic oxyd.

The same reduction of the oxyd of lead was found to take place equally well in ammoniacal gas as in hydrogen, (for ammonia is composed of azot and hydrogen) and this strikingly confirms the other experiments. From $5\frac{1}{2}$ ounce measures of ammoniacal gas, Dr. Priestley got, by means of heating litharge in it, 17 grains of lead, besides some that was dissolved in the mercury confining the gas. The residue was $2\frac{1}{2}$ ounce measures of *azotic gas*, the other constituent of the ammonia.

The reduction of the metals by hydrogen is well shewn by Mrs. Fulhame's^d experiments on this subject. The object of the experiments was to imitate gold and silver brocade by the very ingenious idea of moistening the silk or other substance to be brocaded with the solution of gold or silver or any other metal, and to revive the metal in the pores of the silk by exposing it to some reducing operation. Among others the effect of a current of hydrogen gas was tried. It was found essential to the reduction that the cloth or silk should always be kept moist while in contact with the hydrogen, otherwise the reducing process is very languid and imperfect.

A bit of silk was immersed in a dilute nitromuriat of gold and dried in the air. It was then exposed for half an hour, *dry*, to a current of hydrogen gas, but no signs of reduction appeared: but a similar bit exposed in the same way when *wet* shewed instant signs of reduction, the yellow colour of the solution began to turn green, and very soon a film of reduced gold glittered on the surface opposite to the gas.

^b Phil. Trans. vol. 93, p. 276.

^c Priestley on Air, vol. 1, p. 250.

^d Fulhame's Essay on Combustion.

Shortly after a beautiful blue spot fringed with orange and purple appeared in the middle of the silk. The solution of gold should be first evaporated to dryness and then redissolved in distilled water to get rid of the excess of acid.

A bit of silk dipped in a dilute nitrate of silver and exposed wet to a current of hydrogen soon became brown, which colour gradually deepened and the opposite surface of the silk was coated with a film of reduced silver.

Platina was reduced in the same way.

Mercury was reduced very speedily and beautifully without any preceding brown spot, as in the foregoing instances.

Most of the other metallic solutions were reduced in a similar manner, but the thin metallic pellicle very speedily tarnished.

Hydrogen exercises its deoxygenating powers on many other substances. Dr. Priestley found sulphuric acid to be completely decomposed by it, assisted by heat, and to deposit sulphur. For this purpose he threw the focus of a lens on a quantity of sulphuric acid contained in a hollow vessel, and the whole inclosed in a large receiver full of hydrogen gas and evaporated the acid to dryness. In consequence, the receiver became incrustated with a white film, of which enough could be scraped off to produce the blue flame and smell of true sulphur when laid on a hot iron.

A singular and amusing property has lately been found in hydrogen. Let a bottle be filled nearly full of the materials to produce this gas rapidly (for which purpose bits of zinc and dilute sulphuric or muriatic acid are best), and let this bottle be closed with a cork into which is cemented a bit of tobacco-pipe or a glass tube drawn out into a small bore, and kindle the gas as it issues through the tube, waiting a short time however lest any remaining atmospheric air in the bottle produce an explosion. This will give a vigorous jet of fire about half an inch to an inch long. Then provide a portion of a straight glass tube of about a foot in length, more or less, and open at both ends, and hold it vertically over the flame so that it may just enter the lower end of the tube, and immediately an extremely loud shrill sound will be heard, producing a vibration almost painful to the ears and very sensible to the hand that holds the tube. At the same time the jet of flame will be drawn up the tube, as through a chimney, with extreme vehemence, and if thrust up a little higher, it will be blown out by the strength of the draught. Different lengths and diameters

of tubes may be used to produce different varieties of tone at pleasure. No other jet of burning vapour will produce this effect, which therefore seems to be owing, as Dr. de la Rive has suggested, to the very rapid vacuum which the burning hydrogen occasions, which, assisted by the heat, causes so powerful a draught of the lower air through the tube.

The only use to which hydrogen gas has been applied is that of filling balloons. For this purpose it has generally been found to be cheaper and more commodious to use dilute sulphuric acid and iron turnings or refuse bits of various kinds, and sometimes zinc, though more rarely, because iron is cheaper, and the residuary sulphate of iron is a more saleable article than the sulphate of zinc. To fill a balloon, the materials are put into a number of wooden casks, from each of which proceeds a tin tube that conveys the gas to a common channel, which is a tube of well varnished canvas or leather, which opens in the belly of the balloon. In France, at the military balloon establishment at Verdun, the production of hydrogen by passing steam over red-hot iron in large cylinders was adopted.

Hydrogen dissolves a variety of substances with which it comes in contact, particularly at the moment of its production or its *nascent* state when heated strongly with them. It is not improbable that as commonly prepared it may volatilize and hold in gaseous solution a portion of iron or zinc, to which may be ascribed part of its fetid smell, and it is certain that it will thus dissolve a very sensible portion of *Arsenic*, which it again in part deposits. The other and more important combinations of hydrogen are those in which it holds dissolved a portion of *Sulphur*, of *Phosphorus* and of *Carbon*. These gases are described respectively under the articles *Arsenicated Hydrogen*, *Sulphuretted Hydrogen*, *Phosphuretted Hydrogen*, and *Carburetted Hydrogen* (*which see*.)

HYDRO-SULPHURET is the combination of sulphuretted hydrogen with an alkaline, earthy or metallic base. See **SULPHURETTED HYDROGEN**.

HYDROTHIONIC ACID is a term given by some German chemists of eminence, to **SULPHURETTED HYDROGEN**, (*which see*).

HYDROMETER is an instrument whereby to ascertain the specific gravities of bodies. (*See the Appendix*.)

HYDROPHANE. See **OPAL**.

ICE. See FREEZING.

ICELAND SPAR. See LIMESTONE.

IDOCRASE. See VESUVIAN.

INCINERATION, is nearly synonymous with *Calcination*, and means the burning of any substance to ashes.

INDIGO OR ANIL.

This most valuable pigment, which forms so important a part of West and East Indian commerce, is usually brought over in square or oblong cakes of an intense blue colour, almost black in mass, brittle and friable, light when of a good quality, and of a very peculiar and disagreeable smell.

Indigo is usually reckoned by chemists as a kind of fecula, but of a very peculiar nature not exactly resembling any other known substance. It is prepared by fermentation of the leaves of the indigo-plant, of which the method is shortly the following: ^{a b}

There are three principal varieties of the indigo-plant known and used in the West Indies, in Carolina, and the rest of the American continent, from each of which much indigo is obtained: one variety, which is the smallest, is the *Indigofera Tinctoria*, Linn. (called by the French *Indigo-franc*), which is a delicate plant rather difficult of cultivation, but which yields indigo in abundance and with ease: a second variety is the *Indigofera Argentea*, Linn. (*Indigo bâtard*.) which is hardy and easily cultivated, and gives a very fine indigo: and a third variety is the *Indigofera Disperma*, Linn. (*Indigo Guatimala*), which much resembles the last mentioned.

The seed of the plant is sown in about March or April, at Saint Domingo, and the plant comes into flower about three months afterwards, at which time it is in full maturity and is then cut. If it is gathered before flowering, the indigo which it yields is of a finer colour, but much less in quantity.

The chief apparatus of an indigo-house consists of three wooden vats, of different sizes, and arranged on different levels, so that the contents of the first may flow into the second, and of the second into the third. The first is the steeping vat, in which the plant ferments with water; the second is a vat in which the thick fermented mass is beaten violently by machinery; and the third is that in which the indigo settles when fully formed.

The plant being cut, is first laid into the steeping vat so as to fill it entirely but without

pressing, and is covered about three inches with water. A frame of heavy wooden bars is then laid on the vat to keep the plant down when working. Fermentation soon begins in these hot climates, and the whole contents of the vat swell and foam prodigiously like a wine vat in full action, and with disengagement of large bubbles of gas, which as they burst appear of a lively green, and tinge the whole vat of the same colour. When this process is at the highest the fermenting mass is also covered with a brilliant copper-coloured scum, which passes into violet towards the end, but the pulp and liquor beneath remain green.

The gas given off during the process is inflammable and readily takes fire by applying a lighted candle, and the heaving of the scum is so powerful as often to lift up the heavy wooden frame above mentioned.

The fermentation is known to be carried on long enough by taking samples of the fermenting mass at different times, which when perfect appears as a liquor holding suspended a distinct green pulp, that by a little agitation speedily and completely separates and falls to the bottom of the cup, leaving a clear supernatant gold coloured liquor. Much practical skill is required to seize the exact point when to stop the fermentation, which requires in general from twelve to sixteen hours.

The whole turbid green liquor is then let out of the fermenting or steeping vat and passes into another vessel where it is violently beaten either by the repeated fall of buckets, or by a more complicated mechanical contrivance. This has the effect of checking the further fermentation, of preventing putridity, and especially of promoting in a remarkable degree the separation of the *grain* as it is called, or the dark-coloured granular pulp which is the indigo. The whole liquor and pulp during the process change from green to deep blue by the agitation. It is also the custom in many places to add lime-water to the pulp at this time, which is thought to hasten the graining. A large quantity of air-bubbles is also expelled by the beating.

When the grain separates readily and completely by a little rest from the liquor that holds it suspended, the beating is stopped, and the grain slowly subsides. The supernatant liquor is then drawn off by cocks and suffered to run to waste, carefully avoiding to mix it with any brook or drinking pond which it

^a Nouv. Dict. d'Hist. Nat. art. Indigo.

^b Bancroft on Colours.

would poison and render dangerous for animals to use. The thick dark-blue pulp is then let off into the lowest vat, out of which it is laded into common sacks, which when full are hung up that the water may drain off, the indigo itself being too thick to pass through. The indigo is then transferred to small wooden boxes where it is further dried by alternate exposure to sun and shade, and as it becomes solid is cut into square cakes. It is not yet perfect however, for if exported in this state it would mould and spoil, so that a second fermentation is necessary. For this, the cakes are heaped in a cask, and simply suffered to remain for about three weeks. During this time it undergoes a kind of fermentation, heats, sweats at the surface, gives out a disagreeable smell, and is covered with a fine white meal. It is then taken out and dried in the shade for five or six days when it is quite complete.

This, with some slight variations in different plantations, is the general way of preparing indigo, which therefore may be defined to be a fecula or pulverulent pulp separated from the fibre and juices of the entire plant by fermentation, and materially changed by the process, and doubtless by exposure to the atmosphere, so as to pass from green to a deep blue, and from a soluble to an insoluble state.

Indigo is generally packed in chests of about two hundred pounds weight each. The very fine kind that comes from Guatemala is usually wrapped up in goats' skins.

Very singular chemical properties have been discovered in indigo by different experimenters, among whom may be particularly mentioned Bergman, Haussman,^c and Bancroft. The most singular circumstance concerning indigo, is the insolubility of the blue colouring part in every *simple* menstruum hitherto known (except the sulphuric acid) without such an alteration as entirely destroys the colour for which it is so much valued.

Water boiled long upon indigo (the finest and purest kind being always supposed, as the ordinary sorts are largely adulterated) dissolves about a ninth according to Bergman, or a twelfth according to Quatremere, of the weight.^d The solution is of a reddish brown colour, and contains what may be called the extractive part, but the colouring portion remains absolutely unaltered, and somewhat of a brighter hue. The watery solution is astringent and mucilaginous.

Alcohol dissolves a still smaller portion than

water, and the colouring part remains equally untouched. Ether has nearly the same effect. Neither the fixed nor the volatile oils have any effect on indigo.

The sulphuric acid is the only single agent that dissolves indigo without destroying its colour, and its application as a dye, in which circumstance it is called *Saxon blue*, has been mentioned under the article *Dyeing*.

The acid should be tolerably concentrated to dissolve the indigo, and it may be used quite concentrated without detriment, at least in small quantities. A moderate heat much assists its action, but if too high, the indigo becomes partially burnt or charred, sulphuric acid gas is given out, and all the portion thus altered remains insoluble and is spoilt. The following recipe for the sulphat of indigo, or Saxon blue, is given by Mr. Woulfe.^e Mix one ounce of the best powdered indigo with four ounces of oil of vitriol, in a glass matrass, and digest it for one hour in the heat of boiling water, shaking the mixture several times, then add twelve ounces of water to it, stir the whole well, and when cold filter it. This produces a very rich deep blue colour, of a much brighter hue than any of the other solutions of this pigment, but not a fast colour upon animal or vegetable fibre. The colouring power is very great, a few drops of this solution giving a very sensible blueness to a considerable bulk of water.

The nitric acid acts upon indigo with great vehemence, and in a very singular manner. If on a dram or two of finely powdered indigo be poured about an ounce of fuming nitrous acid, in a short time the mixture heats violently, sends forth a copious flow of nitrous gas, with a stream of sparks, and the whole ends with bursting into flame. When diluted, the acid acts much more mildly, but always with the entire destruction of the blue colour, and in its stead produces a yellow astringent liquor, which is pretty fast upon cotton or cloth dipped in it. This solution however is useless in manufacture. Mr. Haussman has examined with some minuteness the action of nitric acid on indigo.^f On adding at intervals four ounces of powdered indigo to 16 ounces of common aqua fortis heated a little, a great swelling and disengagement of nitrous gas took place, and a coagulum was left, which when washed with cold water, formed a brown, viscous, and very brittle mass, in appearance like a gum-resin, dissolving in alcohol with ease, but not easily in water, except

^c Jour. Phys. for 1788.

^d Jour. Phys. tom. x & xi.

^e Phil. Trans. vol. lxi.

^f Journ. Phys. for 1788.

in a large dose, and hot. The acid liquor in which the coagulum was formed, when evaporated and cooled, let fall more of the same bitter resinous matter, after which it deposited a large quantity of crystals resembling oxalic acid in appearance, but bitter to the taste, and totally differing from it in chemical properties. The nature of these crystals is not well known. An anonymous writer in Nicholson's Journal,² on repeating the above experiments, and using a very large quantity of acid, by repeated distillations nearly destroyed the resinous matter, and obtained in the receiver a clear yellow liquor, strongly smelling of bitter almonds, which suggested the idea of its being prussic acid; however after adding alkali to it and sulphat of iron, no blue precipitate was produced.

The oxymuriatic acid acts but feebly on indigo in decomposing or disorganizing it, but destroys the blue colour totally and speedily. Hence the sulphat of indigo has ingeniously been applied as a measure of the intensity of the bleaching power of the oxymuriatic acid.

None of the other acids exert any apparent action on the colouring matter of indigo.

None of the alkalies, nor alkaline earths, either mild or carbonated, when used alone, have any action whatever on indigo in its blue or perfect state. But to effect a solution of it in alkalies, it is necessary to use some addition, which appears first to change the indigo, and bring it back to a state resembling the recent pulp during the process of manufacture. This at least is made probable by the change of colour that precedes the solution in alkalies, and appears an essential circumstance, and this change is from blue to green of various shades, with a brilliant pellicle on the surface, of the colour and gloss of reguline copper, or rather brighter. This same change, but in a reverse order, takes place in the fermentation of the plant, and process of manufacture; that is, the colour is at first green, with a copper-coloured pellicle, and finally blue.

Indigo not only requires to be changed from the blue to the green state, before it will dissolve in alkalies, but when the solution is made, it only remains dissolved, as long as it continues green, or greenish yellow; for when by any means it resumes its blue state, it immediately becomes insoluble, and separates from the alkaline liquor in form of a dark blue mud, or sediment. Exposure to the atmosphere regenerates blue indigo in a remarkable manner,

so that if a drop of the solution be poured on paper, the surface turns from green and yellow to blue in a very few seconds, which last colour may be again removed (but irrecoverably so) by the oxymuriatic acid. From these and other circumstances, Dr. Bancroft infers, that the cause of the change arises from the different degree of oxygenation, the green being in the lowest state of oxygenation, and the blue in the highest. The substances that form proper additions to enable alkalies to dissolve indigo are very numerous, and very discordant in their nature, for not only have the metallic sub-oxys this power, (as might be expected) but even almost every soluble vegetable matter has the same, such as sugar, raisins, bran, &c. &c. A very simple, and efficacious way of dissolving indigo, is by means of the oxyd of tin, for which, let some well saturated muriat of tin be super-saturated with potash, so that the precipitate at first formed, may be redissolved, and the solution converted into an alkaline one, after which, indigo will dissolve in it readily, and assume almost instantly a deep green colour.

The particular methods of preparing these solutions in the indigo vats, for the use of the dyer, are described sufficiently under the article DYEING.

The analysis of indigo by fire only, affords but little insight into its composition. When distilled *per se*, some ammonia and a peculiar oil rise, and if afterwards burnt away, nothing remains but a very small portion of a very light brown powder or ash. This is a tolerable test of its goodness, as there is hardly any vegetable that leaves so small an ash.

The immense use of indigo in dyeing, has already been fully noticed. At present by far the greater part of what is employed in England, comes directly from the East Indies.

INFLAMMABLE AIR. See HYDROGEN. INFLAMMATION.

Inflammation may be defined to be combustion attended with flame. To what is given on this subject under the article CALORIC, some observations may here be added on the spontaneous inflammation of various substances, on which some important facts have been collected.

Some of the causes of the spontaneous inflammation of combustible substances are too well known to require to be enlarged upon. Of this kind are friction, the heat produced by the slacking of lime when in contact with combustible matter, the fermentation of hay, of dunghills, &c.

But besides these more common causes, experience has shewn that many vegetable substances, highly dried and heaped together, will heat, scorch, and at last burst into flame. Of these, the most remarkable is a mixture of the expressed oil of the farinaceous seeds, as rape or linseed oil, with almost any other dry vegetable fibre, such as hemp, cotton, matting, &c. and still more, if also united with lamp-black, or any carbonaceous substance. These mixtures if kept for a time undisturbed in close bundles, and in a warm temperature, even in small quantities, will often heat, and burn with a smouldering fire for some hours, and if air is admitted freely, will then burst into flame. To this without doubt may be attributed several accidental conflagrations in storehouses, and places where quantities of these substances are kept, as has been proved by direct experiment.

The most important of these were made by Mr. Georgi, and a committee of the Royal Academy at Petersburg, in the year 1781, in consequence of the destruction by fire, of a frigate in the harbour of Cronstadt; the conflagration of a large hemp magazine in the same place in the same year; and a slight fire on board another frigate, in the same port, in the following year.^a

These accidents led to a very strict examination of the subject, by the Russian government, when it came out, that at the time of the second accident, several parcels of matting, tied with packthread, in which the foot of burnt firewood had been mixed with oil, for painting the ship, had been lying some time on the floor of the cabin whence the fire broke out.

In consequence of which, the following experiments were made.

Forty pounds of fir-wood foot were soaked with about 35 pounds of hemp-oil varnish, and the whole was wrapped up in a mat, and put into a close cabin. In about sixteen hours it was observed to give out a smoke, which rapidly increased, and when the door was opened, and the air freely admitted, the whole burst into a flame.

Three pounds of fir-black were mixed with five pounds of hemp-oil varnish, and the whole bound up in linen, and shut up in a chest. In sixteen hours it emitted a very nauseous putrid smell and steam, and two hours afterwards it was actually on fire, and burnt to ashes.

In another experiment, the same occurrences took place, but not till the end of forty-one hours after the mixture had been made; and in

these and many similar experiments, they all succeeded better, and kindled sooner on bright, than on rainy days. Chimney foot used instead of lamp-black did not answer, nor was any effect produced, when oil of turpentine was substituted for the hemp or rape oil. In general, it was found, that the accension took place more readily with the coarser and more unctuous fir-black, than with the finer sorts, but the proportions of the black to the oil, did not appear to be of any great moment.

Sometimes in wet weather, these mixtures only became hot for some hours, and then cooled again, without actually taking fire.

In all these cases, the foot or black was from wood, and not coal.

The presence of lamp-black, or any other dry carbonaceous matter, is not necessary however, for a spontaneous inflammation will take place in hemp or cotton, simply soaked in any of these expressed oils, when in considerable quantity, or under circumstances favourable to this process, as in very hot weather, or closely shut up. An accident of this sort happened at Gainsborough in Lincolnshire, in July 1794,^b with a bale of yarn of 120 lb. accidentally soaked in rape oil, which after remaining in a warehouse for several days, began to smoke, to emit a most nauseous smell, and finally to burst out in a most violent flame.

A similar accident with a very small quantity of the materials, happened at Bombay.^c A bottle of linseed oil had been left standing on a chest, this had been thrown down by accident, in the night, the oil had run into a chest which contained some coarse cotton cloth, and in the morning the cloth was found scorching hot, and reduced nearly to tinder, and the wood of the chest charred on the inside.

On subsequent trial, a piece of the same cloth was soaked in oil, shut up in a box, and in no longer time than three hours, it was found scorching-hot, and on opening the cloth, it burst into fire.

Similar to this, is the spontaneous combustion of wool or woollen yarn, which has occasionally happened when large quantities have been kept heaped up in rooms little aired, and in hot weather. The oil with which wool is dressed, which is generally rape oil, appears the chief agent in this combustion.

Even high dried oily, or farinaceous matter of any kind, will alone take fire, when placed in circumstances very favourable to this process.

Rye flour roasted till half parched, and of

^a Tooke, Repertory, vol iii.

Repertory, vol iii.

^c Phil. Transf. vol. 84.

the colour of coffee, and wrapped up in a linen cloth, has been found to heat violently, and to destroy the cloth.

Wheat flour, when heated in large quantities, and highly dried, has been known to take fire in hot weather, causing accidents in granaries and baker's shops.

An accident of this kind is related by Count Morrozzo, in the memoirs of the Turin Academy,^c to have happened at a flour warehouse at Turin, containing about 300 sacks of flour. It began by a violent explosion on a lamp being brought into the warehouse, and the whole was soon after in flames.

Charcoal alone also has been known to take fire in powder-mills, when quantities of it in powder have been kept for some time closely packed.

Another, and totally different species of spontaneous combustion, is that which occurs during the oxygenation or vitriolization of pyrites, or sulphurets of iron, copper, &c.

A most curious, and if it were not well authenticated, a scarcely credible species of spontaneous inflammation, is that which has in a few rare instances been known to occur in the human body.

It is not quite certain indeed whether the first inflammation has been quite spontaneous, or caused by the approach of a lighted substance; but in these melancholy accidents, the body of the unfortunate sufferers has been brought to a state of such high combustibility, that the flame once kindled, has gone on without other fuel, to the entire destruction of every part, (the bones and extremities excepted) and, as appears, attended with actual flame, of a lambent faint light. This change is the more remarkable, as the human body in all its usual states, both of health and disease, is scarcely at all of itself combustible, and cannot be reduced to ashes without the assistance of a very large pile of faggots, or other fuel, as universal experience in the very ancient mode of sepulture, and the history of martyrdoms, abundantly shews.

The cases of this human combustion on record, have occurred in different countries. Two of them, well authenticated, are recorded in the Philosophical Transactions,^a and have occurred in England, and a few others in Italy, France, and elsewhere. In all but one, the subjects of them have been females rather advanced in life, of indolent habits, and apparently much addicted to spirituous liquors. The

accident has generally been detected by the penetrating fetid smell of burning and footy films, which have spread to a great distance, and the sufferers have in every instance been discovered dead, and with the body more or less completely burnt up, leaving in the burnt parts, only an oily, crumbly, footy, and extremely fetid matter. Another circumstance in which these cases all agree, is the comparative weakness of the heat produced by this combustion, notwithstanding the very complete disorganization of the body itself, so that the furniture of the room, wooden chairs, &c. which were found within reach of the burning body, were in many instances, absolutely unhurt, and in others, only scorched, but the heat was not strong enough to set them actually on fire.

It is impossible to give an adequate reason for this most remarkable change, nor does it seem before the very time of the accident to have produced any very sensible alteration in the appearance, and the functions of the body,—a most astonishing circumstance.

With regard to the effect which the use of ardent spirits is supposed to have here, it is impossible not to imagine that this cause may contribute largely to this change; but the instances of the abuse of spirits are so innumerable, and those of this surprising combustion, are so extremely rare, that very little satisfaction can be obtained from this explanation.

INFUSION

Is the maceration of any substance in water, or any other liquid, hot or cold, with a view of extracting its soluble parts. The liquid thus impregnated is called an *Infusion*.

INGOT.

An ingot is a small bar of metal made of a particular form and size, (generally a very long parallelopiped) by casting it in hollowed iron or brass plates, called *ingot moulds*. It is chiefly to the small bars of gold and silver that the term ingot is applied.

INK. *Common writing.*

The preparation of common writing ink, is a subject of great importance in technical chemistry. A good ink is of a proper consistence to flow freely from the pen, of a full deep black, so permanent as to remain for a number of years without materially fading, or becoming illegible, dries very soon after writing with it, and does not considerably corrode, or soften the pen. The basis of all the common writing inks is the fine black, or dark blue precipitate, formed

^a Repertory, vol. ii.

^c Vol. 43 and 64.

by the addition of vegetable astringents, and particularly the soluble part of the gall-nut, to a solution of iron, generally the sulphat. But as this, if diffused in water alone, would subside in a short time, and leave the supernatant liquor nearly without colour, the precipitate is kept suspended, by thickening the water with gum arabic, or any other gum mucilage, which also gives the ink the due consistence, and enables it to trace a fine stroke on the paper without running. These materials therefore, that is, gall-nuts, green vitriol, (sulphat of iron) gum arabic, and water, are all that are necessary for the composition of ink, and if they are of good quality, and properly proportioned to each other, every other addition usually made, adds very little to its perfection.

It is not well ascertained how soon the present kind of writing ink came into use. It has certainly been employed for many centuries in most European countries, but the antient Roman inks were for the most part of a totally different composition, being made of some vegetable carbonaceous matter like lamp-black, diffused in a liquor. The Chinese and many of the other inks used by the Oriental nations, are still of this kind.

On the subject of the common writing ink, Dr. Lewis^a has so full and so accurate an investigation, and his experiments are so simple and well devised, that little else can be added to the subject in a technical point of view. For a fuller chemical enquiry into the nature of the atramentous precipitate, the reader is referred to the articles GALLIC ACID and IRON.

Dr. Lewis first endeavoured to ascertain the best proportion between the galls and the sulphat of iron, to render the ink permanent; for it is to be observed that with almost any proportions, if the entire quantity be sufficient, the ink will be fine and black at first, but many of these inks if kept for some time, especially exposed to light and air, will grow brown and fade, and the letters made with it will become nearly illegible.

By trying different proportions of galls and sulphat of iron, it was found that when about in equal quantities (the galls being powdered and boiled fully to extract their soluble parts) they appeared to be mutually saturated, so that the mixed liquors would receive no additional blackness from a further dose of one or the other. This however was only a rough approximation to accuracy, for the same effect was produced when either substance was also in a small

degree superior in quantity to the other. But Dr. Lewis found that an ink with equal parts of the two, though very black at first, changed to a yellowish brown upon exposure to the sun and air only for a few days. This was again blackened by washing with fresh gall-infusion, and hence it appears a fair inference that the galls are in some degree a perishable substance, so that to ensure durability, a much greater proportion must enter into the ink than is required for mere saturation in the first instance. Thus it was found that two parts of galls and one of vitriol, make a much more durable ink than with equal parts, and three of galls with one of vitriol was still more durable. When the galls were increased beyond this point the colour was indeed quite permanent, but it was not of so full a black.

The proportion of water or other liquid to the solid ingredients will admit of great variation. One part of vitriol, three of galls, and fifty parts of water, gave an ink black enough for common use, but the finest and blackest was made when only ten of water were employed; nor was any deficiency in the gallic acid observed after fifteen years, though the water was scarcely more than sufficient to cover the galls, and therefore could hardly be supposed capable of extracting all the soluble part of them, and though the vitriol, from its greater solubility, would probably be dissolved entirely, and thus be in greater proportion than usual. Other liquors besides water were tried. Of these white wine and vinegar appeared to answer somewhat better, but any considerable proportion of spirit of wine, or brandy, obviously did harm, owing to the insolubility of the sulphat of iron (as of all the other sulphats) in alcohol, and therefore its diminished solubility in any liquor is in proportion to the alcohol it contains. A decoction of logwood used instead of water, sensibly improved the beauty of the colour.

Instead of galls other astringents were employed, such as flos, oak-bark, tormentil root, &c. but though they all gave a good blue-black with the salt of iron, none of them was equal to the gall-nut in this respect.

Other salts of iron were also substituted to the sulphat. The muriat and nitrat of iron nearly equalled the sulphat in colour, but proved too corrosive to the paper, and as they were in no respect preferable to the sulphat, there is no reason for abandoning it.

Imagining that there must be some excess of

^a Commerce of Arts.

fulphuric acid in common ink, to which the fading might be imputed, Dr. L. tried to neutralize it by lime and alkalies, but with manifest injury, the colour being rendered thereby extremely fugitive. Another ingenious idea for avoiding the supposed excess of acid, was to separate the black atramentous precipitate, wash it, and again diffuse it with water thickened with gum. This did indeed make a very good ink, but with the capital defect of not remaining so long suspended in the liquor, and especially of not fixing itself to the paper like common ink, but rather only slightly adhering like a weak gum varnish, and was readily washed off by water. Hence it appears that the acid of the salt of iron acts as a kind of mordant or intermede, between the atramentous precipitate and the paper, and causes a degree of chemical union between them: a real advantage which this species of ink possesses over all the lamp-black or China inks, which indeed are rather black varnishes.

With regard to the gummy ingredient, the effect of which is chiefly mechanical, it was found that any other gum-mucilage would answer as well, but not glue, isinglass, nor animal jelly of any kind. Besides as these latter putrify by keeping, this alone would be a strong objection.

Sugar is sometimes added to ink. It makes it flow somewhat easier from the pen, and gives it when dry a gloss which is admired by some. It has this quality however of making it very slow in drying, which in most cases is an inconvenience.

On account of the great improvement to the black atramentous dye produced by adding sulphat of copper (*See the article Dyeing*), some have recommended this addition to common ink, which is composed of the same materials; but it does not appear that the same advantage is here obtained, and Dr. Lewis thinks it an useless addition.

From the above observations Dr. Lewis gives the following receipt for the composition of ink: Put into a stone or glass bottle, or any other vessel, three ounces of finely powdered galls, one ounce of green vitriol, one ounce of logwood finely rasped or bruised, one ounce of gum arabic, and a quart of soft water. Shake the bottle well, and let the ingredients stand in a moderately warm place for a week or ten days, shaking it frequently in the day. It is then fit for use, but a little before it is put into the ink-stand, it is better to shake the bottle that the colour may be more uniformly diffused.

To prevent the ink from moulding, Hoffman recommends half a dozen cloves to be bruised with the gum arabic and put into the bottle. This appears an useful addition. Instead of water alone, where a very fine ink is wanted, white wine or vinegar and water may be used.

If the ink be wanted for use in a very short time, the galls and logwood may be boiled for half an hour in the water, adding a little more to supply the waste, and the decoction while hot strained off through a cloth, and the gum arabic and cloves, and the sulphat of iron, both in fine powder, added to the decoction when in the bottle and shaken. The ink will then be fit for use almost immediately after the latter ingredients are dissolved. It will be improved by adding to the bottle some pieces of gall-nut coarsely bruised.

Ink kept in a close bottle is always rather pale, but it blackens by exposure to air in a few hours, and probably in this way the colour is somewhat more durable than if it were brought by previous exposure to its full colour at once.

It has been mentioned that sugar renders ink slow in drying. Advantage is ingeniously taken of this property in enabling it to give one, and sometimes two impressions on soft paper when strongly pressed. In this simple way letters are copied in merchants counting-houses, and offices of business. A little sugar is mixed with the ink, the written sheet is laid on the copying press, a blank sheet of porous and damped paper is put over it, and by the pressure of the machine a perfect fac-simile of the writing is struck off, sufficiently legible for all purposes.

This ingenious method saves a vast quantity of labour usually bestowed in copying letters, and besides prevents all possibility of mistake.

Sometimes the ink of very old writings is so much faded by time as to be illegible. Dr. Blagden^b in his experiments on this subject, found that in most of these the colour might be restored, or rather a new body of colour given, by pencilling them over first with a solution of prussiat of potash, and then with a dilute acid either sulphuric or muriatic; or else vice-versa, first with the acid and then with the prussiat. The acid dissolves the oxyd of iron of the faded ink, and the prussiat precipitates it again of a blue, which restores the legibility of the writing. If this be done neatly and blotting paper laid over the letters as fast as they become visible, their form will be retained very distinctly. Pencilling over the letters with an infusion of galls also restores the

^b Phil. Trans. vol. lxxvii.

blackness to a certain degree, but not so speedily nor so completely.

The blackness of common ink is almost instantly and irrevocably destroyed by the oxy-muriatic acid, and hence any writing may be effaced by this method completely. To prevent this mischief, which might often be a serious one, several additions have been proposed to common ink, of which by far the best is lamp-black or charcoal, in impalpable powder, on which the acid has no effect. The lamp-black should be of the least oily kind, as it does not readily mix with the ink, and some pains must be taken to incorporate them. On this account perhaps common charcoal is preferable. About a quarter of the weight of the vitriol used will be amply sufficient. This will not fade by age.

INK. *China or Indian.*

The well known and much admired Indian or China ink, is brought over in small oblong cakes, which readily become diffused in water by rubbing, and the blackness remains suspended in it for a considerable time, owing to the extreme subtlety of division of the substance that gives the colour, and the intimacy with which it is united to the mucilaginous matter that keeps it suspended.

Indian ink does however deposit the whole of its colour by standing, when it is diffused in a considerable quantity of water. Dr. Lewis on examining this substance found that the ink consisted of a black sediment totally insoluble in water, which appeared to be of the nature of the finest lamp-black, and of another substance soluble in water, and which putrefied by keeping, and when evaporated left a tenacious jelly exactly like glue or isinglass. It appears probable therefore that it consists of nothing more than these two ingredients, and probably may be imitated with perfect accuracy by using a very fine jelly, like isinglass or size, and the finest lamp-black, and incorporating them thoroughly. The finest lamp-black known is made from ivory shavings, and thence called *ivory-black*.

INK. *Printers.*

This is a very singular composition, partaking much of the nature of an oil varnish, but differing from it in the quality of adhering firmly to moistened paper, and in being to a considerable degree soluble in soap water.

It is, when used by the printers, of the consistence of rather thin jelly, so that it may be smeared over the types readily and thinly,

when applied by leather cushions, and it dries very speedily on the paper without running through to the other side, or passing the limits of the letter.

The method of making printer's ink is thus described by Dr. Lewis.

Ten or twelve gallons of nut oil are set over the fire in a large iron pot, and brought to boil. It is then stirred with an iron ladle, and whilst boiling, the inflammable vapour rising from it either takes fire of itself or is kindled, and suffered to burn in this way for about half an hour, the pot being partially covered so as to regulate the body of the flame, and consequently the heat communicated to the oil. It is frequently stirred during this time that the whole may be heated equally, otherwise a part would be charred and the rest left imperfect. The flame is then extinguished by entirely covering the pot. The oil by this process has much of its unctuous quality destroyed, and when cold is of the consistence of soft turpentine, and is then called *varnish*. After this it is made into ink by mixture with the requisite quantity of lamp-black, of which about $2\frac{1}{2}$ ounces are sufficient for 16 ounces of the prepared oil. The oil loses by the boiling about an eighth of its weight, and emits very offensive fumes. Several other additions are made to the oil during the boiling, such as crusts of bread, onions, and sometimes turpentine. These are kept secret by the preparers. The intention of them is more effectually to destroy part of the unctuous quality of the oil, to give it more body, to enable it to adhere better to the wetted paper, and to spread on the types neatly and uniformly.

Besides these additions, others are made by the printers, of which the most important is generally understood to be a little fine indigo in powder, to improve the beauty of the colour.

For further observations on the nature of fixed oils, and the alteration they undergo by heat, see the article OIL. (*Fixed*.)

Red printers ink is made by adding to the *Varnish* about half its weight of vermilion. A little carmine also improves the colour.^c

INKS. *Coloured.*

Few of these are used except red ink. The preparation of these is very simple, consisting either of decoctions of the different colouring or dyeing materials in water, and thickened with gum arabic, or of coloured metallic oxyds or insoluble powders merely diffused in gum water. The proportion of gum arabic to be used may be the same as for black writing ink. All that applies

to the fixed or fugitive nature of the several articles used in *dyeing*, may be applied in general to the use of the same substances as inks.

Red Ink is usually made by boiling about two ounces of Brazil wood in a pint of water for a quarter of an hour, and adding to the decoction the requisite quantity of gum, and about half as much alum. The alum both heightens the colour and makes it less fugitive. Probably a little madder would make it more durable.

Blue Ink may be made by diffusing Prussian blue or indigo through strong gum-water.

Yellow Ink may be made by a solution of gamboge in gum-water.

Most of the common water-colour cakes diffused in water, will make sufficiently good coloured inks for most purposes.

INKS *Sympathetic or Secret.*

These are all liquids which have scarcely any colour in their common state, and therefore when characters are traced with them on paper they are invisible, or nearly so, at first, but a colour is given to them either by applying some chemical reagent, or by mere heat. A considerable number of these have been invented, some of which may be just enumerated.

The sympathetic ink of cobalt is the best known and the most singular. Any solution of this metal that contains muriatic acid in any form becomes green when heated, but returns to a state nearly colourless when cold. This also will appear and vanish alternately by heating or cooling. When the cobalt is pure the colour approaches strongly to blue. *See Cobalt.*

Characters written with lemon-juice are invisible at first, but on strongly heating the paper, the extractive matter of the lemons turns brown, and thus becomes visible.

Sulphuric acid moderately diluted, answers in the same way. On heating the paper the water of the acid flies off, the latter becomes thereby concentrated, and acts on the paper, making it brown.

Of the secret inks formed by the action of reagents, the metallic solutions that are blackened by a liquid sulphuret, or sulphuretted hydrogen gas, are the best known. These metallic solutions are those of lead, silver, bismuth, and mercury.

The acetite of lead is one of the most convenient. Letters written by any of these solutions, are at once blackened and rendered visible by being wetted with the sulphuretted solution, or more slowly by exposure to the gas. The so-

lutions may be very dilute, as the deepening of colour is very powerful.

A weak solution of gallic acid diluted to be colourless, will also be blackened by any salt of iron.

Prussiat of potash will likewise become blue by any solution of iron.

IRIDIUM. *See PLATINA.*

IRON. *Ferrum.* Lat. *Fer.* Fr. *Eisen.* Germ. *Jern.* Dan. *Jarn.* Swed. *Mars.* Alchem.

Iron is a metal, of a bluish grey colour, hard, ductile and malleable; capable of acquiring magnetic polarity, and of being welded; soluble in the muriatic and most other acids; precipitable in the state of Prussian blue by a prussiated alkali, and assuming a deep bluish-black colour with infusion of gall-nut.

§. 1. *Ores of Iron.* ^a

Sp. 1. NATIVE IRON. *Gediegen Eisen.* Wern. *Fer Natif.* Broch.

Its colour is light steel-grey resembling white cast iron or platina; but it is generally covered by a thin superficial crust of brown oxyd. It occurs branched or cellular. Its lustre is moderately shining and metallic. Its fracture is hackly; it gives a bright streak, may be easily cut with a knife; and is perfectly malleable when cold, and in a moderate heat, but at a high temperature it becomes brittle and granular; it is flexible and difficultly frangible. Sp. gr. not exceeding 6.48.

A mass of native iron, reported by the inhabitants of the country to have fallen from the sky, was found by Professor Pallas in Siberia. Between the rivulets Ubei and Sissim, that run into the Jenisei on the eastern side, is a mountain containing a rich mine of magnetic iron ore; on the same side of the mountain where this mine is situated, was found lying loose on the rock the mass of native iron alluded to, weighing 1680 Russ. lbs. ^b This mass is cellular, and the cells are either empty or occupied by a transparent greenish yellow substance, at first taken for fluor spar, but which on subsequent examination greatly resembles the chrysolite. ^c

A still larger mass of native iron was seen and described by Don Rubin de Celis. ^d It is situated in the district of Otumpa, in the Viceroyalty of Peru; its weight is about 15 ton; it is compact externally, and is marked with impressions as if of hands and feet, but much larger, and of claws of birds; internally it is full of cavities. It is almost imbedded in white clay, and the country round is quite flat and destitute of water. Another mass of iron likened in

^a Emmerling, Lenz, Kirwan, Jameson, Haüy, Brochant.

Transf. xcii. p. 206.

^b Pallas in Phil. Transf. lxvi. p. 523.

^c Phil. Transf. lxxviii. p. 183.

^d Bournon in Phil.

shape to a fallen tree has also been seen in the same territory.

Native iron, in detached masses, and of a cellular texture, has also been found near Tabor in Bohemia, and in Senegal in Africa.

All these specimens of native iron bear a striking resemblance to each other in their being found in casual detached masses on the surface of the earth, in their cellular texture, and in their chemical composition, whence it is probable that they have originated from similar causes, and the hypothesis of their having fallen from the atmosphere appears to be supported by strong analogy as well as vulgar tradition; but for further particulars on this curious subject we refer the reader to the article *STONES meteoric*.

Native iron has also been found imbedded in brown ironstone, spathose ironstone, and heavy spar, at Kamsdorf in Saxony, and is said to have occurred stalactitical with brown ironstone and quartz, forming a vein in the mountain of Oulle near Grenoble.

It is remarkable that the native iron in detached masses, or as Klaproth calls it, the meteoric iron, is in fact an alloy of this metal with nickel, and to this admixture it is no doubt greatly indebted for the long resistance that it makes to the combined action of air and moisture. Common hammered iron is of all metallic substances the most easily corroded by rust, yet the native iron oxydates with great difficulty.

But although chemists are agreed respecting the nature of the ingredients of meteoric iron, they vary remarkably in their accounts of the proportions. This difference is partly to be attributed to a real variation in the proportions, but principally to the different methods that have been had recourse to in estimating the amount of the nickel.

Mr. Howard^e endeavoured to ascertain the quantity of nickel by the following process. He first dissolved some pure bar iron in nitric acid, and precipitated the oxyd by caustic ammonia, and from the result of several experiments found that 100 parts of iron thus treated, afforded 145 of oxyd; but oxyd of nickel is not precipitable by ammonia, therefore in proportion to the nickel contained in the alloy will the oxyd procured fall short of the estimated amount which pure iron would have afforded. Thus 100 grains of the Siberian iron yielded 127 of oxyd of iron, hence the proportion of nickel which it contains, is 12.5 per cent. (not 17 per cent. as Mr. H. has inadvertently stated) for

: 145 oxyd : 100 iron :: 127 oxyd : 87.5 iron ;
therefore the *Siberian* iron consists of

87.5 Iron
12.5 Nickel

100.0

Again in like manner the *S. American* iron yielded 80 grains of oxyd from 62 of the metal; hence it contained, not as Mr. H. states, 10 per cent. but 11 per cent. of nickel, for : 145 : 100 :: 80 : 55.1, hence the 62 grains consisted of 55.1 iron, and 6.9 nickel; therefore 100 parts of this contains

88.9 Iron
11.1 Nickel

100.0

So the *Bohemian* iron gave 30 grains of oxyd from 25 of the metal, and therefore consisted of

82.4 Iron
17.6 Nickel

100.0

Lastly the *Senegal* iron yielded 199 grains of oxyd from 145 of metal, and therefore contained not between 5 and 6 per cent. as Mr. H. states, but

95.2 Iron
4.8 Nickel

100.0

The South American iron has been analysed also by M. Proust,^f but in a different way from that followed by Mr. Howard. M. Proust found that 100 grains of iron wire yielded with dilute sulphuric acid, 200 cubic inches of hydrogen gas; but 100 grains of native iron gave only 176 inches, therefore : 200 : 100 :: 176 : 88, hence the amount per cent. of the two metals is

88 Iron
12 Nickel

100

which agrees very satisfactorily with the proportions indicated by Mr. Howard.

But Klaproth, according to Jameson,^g has analysed some native irons with results, if they are correctly reported, widely differing from those which we have just quoted. According to this able chemist the meteoric iron of Bohemia and Siberia consists of

^e Phil Trans. xcii. p 191.

^f Ann. de Chem. xxxv. p. 47.

^g Mineralog. ii. p. 259.

B.	S.	
96.5	—	98.5 Iron
3.5	—	1.5 Nickel
—	—	—
100	—	100
==	==	==

The proper native iron of Kamsdorf in Saxony, according to the same authority, is composed of

92.5	Iron
6.0	Lead
1.5	Copper
—	—
100.0	—
==	==

Sp. 2. UNMAGNETICAL IRON PYRITES.

Of this there are the five following sub-species.

1. *Subsp.* Common Pyrites. *Gemeiner Schwefelkies*. Wern. *Pyrite martiale commune*. Broch.

Its colour is perfect brassy-yellow, sometimes by tarnishing it is superficially reddish or brownish.

It occurs massive, disseminated, investing, and crystallized. Its primitive crystalline form is the cube, which passes into the following varieties:

1. The cube, with convex faces.
2. The cube with solid angles replaced by triangular facets, so as to be intermediate between the cube and octohedron.
3. The cube with its edges replaced by narrow planes inclined more towards one than the other of the adjacent faces.
4. The cube with the three plane angles that form each of the solid angles, replaced by secondary angles of more than 90°.
5. The octohedron either perfect or with all its solid angles replaced by planes.
6. The dodecahedron with pentagonal faces.
7. The same, with six opposite and parallel edges replaced by narrow planes.
8. The dodecahedron with eight of its angles replaced by planes, forming the passage into the icosaedron.
9. The perfect icosaedron. This variety is extremely rare.
10. The same, with four edges replaced by narrow planes.
11. The triacontahedron, formed of thirty rhombic faces.

The crystals are mostly small, but the cubes are often middle-sized; they are sometimes single, but oftener variously aggregated. The surface of the crystals is generally smooth, but the cubes sometimes occur striated in three directions: their lustre varies from specular to

glistening. Internally it is feebly-shining, with a metallic lustre. Its fracture is coarse or fine-grained uneven. Its fragments are indeterminate angular. It does not yield to the knife; and gives red sparks with steel: it is opaque, brittle, not very frangible, and by percussion affords a sulphureous odour. Sp. gr. of the crystallized, 4.78 : 4.83.

When exposed to the blowpipe on charcoal, it emits a strong sulphureous odour, and burns with a bluish flame. It then becomes a brownish globule, attractable by the magnet, and by a further continuance of the heat passes into a blackish slag.

According to the experiments of Mr. Hatchett,^a the pyrites with smooth cubes consists of

Sulphur	52.70
Iron	- 47.30
—	—
100.0	—
==	==

Pyrites with striated cubes contains

Sulphur	52.5
Iron	- 47.5
—	—
100.0	—

and dodecahedral pyrites contains

Sulphur	52.15
Iron	- 47.85
—	—
100.00	—
==	==

The striated cubes and dodecahedrons sometimes contain gold, and hence are named auriferous pyrites.

Common pyrites occurs in almost every mineral formation, and almost every species of rock. It abounds in granite, and particularly in primitive and transition argillaceous schistus.

It is never wrought as an ore of iron, but is largely employed in the manufacture of green vitriol, and sulphur is often procured from it by sublimation, while the residual red oxyd is valuable as a coarse kind of paint.

2. *Subsp.* Radiated Pyrites. *Strahlkies*. Germ. *Pyrite rayonnée*. Broch.

Its colour is brassy-yellow, but paler than common pyrites; its surface is generally tarnished. It occurs in mass, but most usually in particular forms, such as kidney-shaped, tuberous, globular, botryoidal, scaly, stalactitic, &c. Also in minute crystals between the cube and octohedron. When the crystals are very much flattened and united in diverging groups, they form the cock's-comb pyrites. The surface of the crystals is

^a Phil. Trans. xciv. p. 315.

either smooth or drusy, and therefore their external lustre is subject to corresponding variations. The fracture is for the most part divergingly radiated in stars or bundles, with short striae fibres. It sometimes passes into parallel-fibrous, and even into compact. Its fragments are wedge-shaped. It occurs in coarse and large granular distinct concretions, also in thin curved lamellar, and in thin columnar distinct concretions. It is hard, brittle, and very easily frangible. Sp. gr. 4.69 to 4.77.

It is composed according to Hatchett of

Sulphur	53.6	—	54.34
Iron	46.4	—	45.66
	100.		100.

It is rarer than common pyrites, and occurs principally in small masses, and in veins with ores of lead or silver. In Britain it occurs in Cornwall, the Isle of Sheppy, and Derbyshire. It is remarkably subject to decomposition on exposure to the air and moisture, and hence is much sought after by the manufacturers of green vitriol.

3. *Subsp.* Capillary pyrites. *Haarkies*. Wern. *Pyrite Capillaire*. Broch.

Its colour is bronze yellow, passing into steel-grey. It occurs in delicate capillary crystals aggregated into divergent bundles or promiscuously. In other particulars it agrees with the preceding, of which it is little else than a variety.

It is the least frequently met with of any of the kinds of pyrites. It occurs in veins with lead and silver ores, accompanied by quartz, calcareous and fluor spars, in Saxony and the Hartz.

4. *Subsp.* Cellular pyrites. *Zell-kies*, Wern.

Its colour is bronze yellow inclining to greenish and steel-grey. It becomes of a grey colour by tarnishing. It occurs cellular: its fracture is even and flat conchoidal passing into fine-grained uneven. In other respects it resembles common pyrites, into which it occasionally passes. It is the least subject to decomposition of the whole species. It occurs in metallic veins in Saxony.

5. *Subsp.* Liver pyrites. *Leberkies*, Wern. *Pyrite hepatique*, Broch.

Its colour is intermediate between pale brass-yellow and steel-grey; its external surface is usually brownish or iridescent. It occurs in masses, disseminated, globular, tuberous, reniform, stalactitic and cellular; also crystallized in six-

sided prisms or pyramids. Internally it is usually glimmering, with a metallic lustre. Its fracture is even, passing into fine granular or flat conchoidal. It occurs in distinct concretions. It is met with only in metallic veins and is very subject to decomposition.

Sp. 3. MAGNETICAL PYRITES. *Magnetkies*, Wern. *Pyrite magnetique*, Broch.

Its colour is intermediate between brass-yellow and copper-red, and sometimes inclines to tombac brown: by exposure to the air it acquires a brownish tarnish. It occurs only in masses and disseminated. Internally it is shining or glistering, with a metallic lustre. Its fracture is fine or coarse grained uneven, sometimes passing into imperfect conchoidal. It breaks into indeterminate blunt edged fragments. It affords a few occasional sparks with steel; is brittle and easily frangible. Sp. gr. 4.518.

It is especially distinguishable from the preceding species in being attracted by the magnet and giving out sulphuretted hydrogen by digestion in muriatic acid. Its component parts, according to Mr. Hatchett, are

Sulphur	-	-	36.5
Iron	-	-	63.5
			100.

It is said to be found only in beds in primitive mountains, in gneiss, micaceous schistus, primitive greenstone and limestone, where it occurs with common martial pyrites, copper pyrites, arsenical pyrites, galena, blende, magnetic ironstone, garnet, hornblende, and actynolite. It is met with in Bohemia, Bavaria, and Silesia, also in Norway, and has recently been found by Mr. Greville near the base of Moel Elion in Caernarvonshire, where it forms a thick vein or more properly a bed, as Jameson conjectures. Besides the above localities it occurs disseminated in transition greenstone a little to the south of Pont Aberglaslyn in Caernarvonshire; and forming a large bed with black calcareous spar in transition slate, not far from Trefriew in the vale of Conway, in the same county. At this last place it is procured in considerable quantity for the sulphur which it yields by sublimation and the red ochre which remains after the separation of the sulphur.¹

Sp. 4. MAGNETICAL IRON STONE.

Of this there are the two following subspecies.

1. *Subsp.* Common Magnetic Iron stone. *Gemeiner Magneteisenstein*, Wern. *Fer magnetique commun*, Broch.

¹ Own Observations.

Its colour is iron-black, often superficially tarnished. It occurs massive, disseminated and crystallized. The forms of its crystals are,

1. The octohedron.
2. The garnet dodecahedron.
3. A rectangular four-sided prism, terminated by four-sided pyramids.

The crystals are usually either imbedded or accumulated on each other, and are small and middle-sized. The internal lustre varies between bright-shining and glimmering, and is metallic. Its fracture is generally coarse or fine granular, uneven; sometimes also small conchoidal and imperfectly lamellar. It sometimes, though rarely, occurs in coarsely granular and very loose distinct concretions. It gives a brownish black streak and is considerably hard. The crystals are very difficultly frangible, but the granular varieties are more easily broken. Sp. gr. 4.2 to 4.9.

It is not only attractable by the magnet, but itself possesses polarity, hence it takes up iron filings. Before the blowpipe it becomes brown and tinges glass of borax of a dark green colour. It has not been regularly analyzed, but is supposed to be nearly a pure oxyd of iron. When smelted in the large way it is said to yield from 80 to 90 per cent. of metal, but this is manifestly impossible; a more probable estimate is from 60 to 70 per cent. It occurs most frequently in primitive mountains and chiefly in gneiss, micaceous schistus, chlorite slate, and primitive limestone: also in serpentine, and in the floetz-trap formation. When in mass it forms beds and sometimes considerable rock-masses. It is usually accompanied by hornblende, granular limestone, and garnet; also, though more rarely, by amianth, actynolite, fluor spar, coccolite, fahlite, augite, all the varieties of pyrites, blende, tinstone and galena.

The Mountain Taberg in Swedish Lapland, and Pumachanche in Chili, are said to consist almost entirely of this mineral. It exists in great abundance and purity in Roslagia in Sweden, where it is manufactured into the best bar iron, so much sought after by the English manufacturers of steel. It also occurs in sufficient plenty to be smelted in the islands of Corsica and Elba; Arendahl in Norway; in Saxony; Bohemia, Silesia, and the Hartz in Germany; in many places among the Uralian mountains in Russia; and in Siam in the East Indies.

When pure it affords the best bar iron, but only middling cast iron: it is easily fusible and requires but little flux.

2. *Subsp.* Magnetic iron sand. *Eisensand*, Wern. *Fer magnetique sablonneux*, Broch.

Its colour is deep iron black. It occurs in angular and roundish grains from the smallest dimensions to the magnitude of a hazel-nut; also in octohedral crystals. Both the grains and crystals are externally somewhat rough and glimmering. Internally it exhibits a bright-shining metallic lustre. Its fracture is perfectly conchoidal and rarely imperfectly foliated. Its fragments are indeterminate and sharp-edged. It gives a greyish-black powder. It is moderately hard, brittle and easily frangible. Sp. gr. 4.6.

It is powerfully attracted by the magnet, but is scarcely at all acted on by the muriatic or nitric acids.

It seems to belong almost entirely to the floetz-trap formation, and is found imbedded in basalt and wakke or loose in the beds of rivers. It does not often occur in sufficient abundance to be smelted, yet it is employed for this purpose in the Tyrol, near Naples, and in Virginia, and produces about 60 per cent. of excellent bar iron.

Sp. 5. SPECULAR IRON ORE. *Eisenglanz*, Wern.

Of this there are the two following subspecies.

Subsp. 1. Common Specular Iron ore. *Gemeiner Eisenglanz*, Wern. *Fer speculaire commun*, Broch.

Its usual colour is deep steel-grey, passing sometimes in the crystallized varieties to iron black, and in the massive varieties to brownish red. It is often tarnished externally, and then presents the blue and yellow tints of tempered steel. It occurs in mass, disseminated and crystallized. The forms of its crystals are,

1. A compressed hexahedron composed of two three-sided pyramids set base to base with the angles of the one corresponding with the sides of the other.
2. The same, with the angles at the base truncated.
3. The cube with its edges replaced by narrow planes.
4. A double six-sided prism deeply truncated.
5. A six-sided table: sometimes several of these are grouped together so as to form cells.
6. A low equiangular six-sided prism.
7. Lenticular.

The planes of the crystals are sometimes smooth and sometimes striated, but in the cube are always striated diagonally. Its external lustre is generally bright-shining metallic. Its fracture is compact or foliated; the compact is

granular uneven passing into imperfect and small conchoidal; the foliated has a fourfold rectangular cleavage. Its fragments are octohedral or pyramidal, sometimes indeterminately angular. It sometimes though rarely presents granular distinct concretions, also imperfectly wedge-shaped and more frequently thick lamellar, either straight or curved, distinct concretions. The colour of its streak is cherry-red. It is hard, brittle, not very easily frangible. Sp. gr. 4.7. to 5.2.

When pulverized it is slightly magnetic. It is infusible *per se*, before the blowpipe; with borax it gives a dirty yellow slag. According to Kirwan it consists of iron and oxygen in the proportion of from 60 to 80 of the former and from 20 to 30 of the latter.

It occurs in beds and veins in primitive and transition mountains, and is generally accompanied by magnetic iron-stone and compact red iron-stone, iron pyrites and quartz. The greater part of the iron ore of Elba is of this species; it also abounds in Sweden and Norway, in Bohemia, Saxony, Silesia, Switzerland, France, Russia, and Siberia. It affords an excellent malleable iron, but somewhat hard, and also a good but not the very best cast iron.

2. *Subsp.* Micaceous iron ore. *Eivenglimmer*, Wern. *Fer micacée*, Broch.

Its colour is iron-black passing into steel-grey; and the thin plates of which it consists when held between the eye and the light appear blood-red. It occurs massive, disseminated, or superficial, or crystallized in thin hexahedral tables, which sometimes intersect one another so as to form cells. The surface of the crystals is smooth and almost specular. Internally it is more or less shining, with a metallic lustre. Its fracture is perfectly foliated; the lamellæ are curved and divisible only in one direction. Its fragments are either indeterminate or in the form of plates. When in mass it occurs in thin and curved lamellar or granular distinct concretions. The thin plates are sometimes faintly translucent. The colour of its streak is cherry red. It is moderately hard, but becomes soft in proportion as it passes into the red scaly iron ore; it is brittle and easily frangible. Sp. gr. 4.5 to 6.0.

It occurs only in primitive mountains, but chiefly abounds in the most recent of these. It lies in beds and veins accompanied by red and brown iron-stone and iron pyrites.

It affords on analysis upwards of 70 *per cent.* of iron. In the great way it is found to melt more easily than the preceding subspecies, pro-

vided a sufficient quantity of limestone is added to it by way of flux. The iron that it affords is sometimes cold-short but is well fitted for cast ware.

It is met with in Norway, Sweden, various parts of Germany, Dauphiné in France, Piedmont and the island of Elba in Italy, the forest of Dartmoor in Devonshire, near Dunkeld in Perthshire, and in Mainland, one of the Shetland islands.

Sp. 6. RED IRONSTONE. *Rotheisenstein*, Wern. Of this there are four subspecies.

1. *Subsp.* Red scaly iron ore. *Rother Eisenrahm*, Wern. *Eisenrahm rouge*, Broch.

Its proper colour is cherry red, but it also passes into blood-red, brownish-red, steel-grey and iron-black. It occurs sometimes in mass, but more frequently as a superficial covering to other ores of iron. It is glistening, with a semi-metallic lustre. It is composed of friable scaly particles more or less cohering together. It stains the fingers, is unctuous to the touch, and moderately heavy.

When exposed to the blowpipe without addition it blackens but does not melt. It communicates to glass of borax an olive green colour.

Its component parts, according to Mr. W. Henry^k, are

Iron	-	-	66.
Oxygen	-	-	28.5
Silex	-	-	4.25
Alumine	-	-	1.25
			=====
			100.00
			=====

It occurs usually in veins in primitive mountains, also in transition mountains. It is commonly accompanied by the other subspecies of red ironstone and spathose iron. It passes into micaceous iron ore.

It is found at Ulverstone and other places in the North of Lancashire. At Sahl in the Dutchy of Henneberg it is smelted and produces very good iron.

2. *Subsp.* Red Ochre. *Ockricker Rotheisenstein*, Wern. *Ochre de Fer rouge*, Broch.

Its colour is blood-red passing into brownish red. It is found in mass, disseminated and superficial. It has little or no lustre. Its fracture is earthy. It stains the fingers; is usually friable and very tender, but in some varieties passes into solid: to the touch it is smooth and somewhat meagre. Sp. gr. 2.95.

It is found accompanying the other subspecies

^k Nicholson's Journ. 4to. vol. iii. p. 454.

of red iron-stone, but rarely in any considerable quantity. It is smelted in the Irrgange near Platte in Bohemia, is very fusible, and affords excellent malleable iron.

3. *Subsp.* Compact red Iron-stone. *Dichter Rotheisenstein*, Wern. *Mine de Fer rouge compacte*, Broch.

Its colour is intermediate between brownish red and dark steel-grey, it passes sometimes to blood-red. It occurs in mass or disseminated, or in particular shapes, such as globular reniform, specular, cellular, in pseudomorphous pyramidal crystals or rarely in real cubic crystals either solitary or in groups. The surface of the true crystals is smooth, of the others rough. The external lustre is subject to several variations: internally it is rarely more than glimmering, semi-metallic. Its fracture is commonly even, whence it occasionally passes into coarse grained uneven and large conchoidal: sometimes also it is found flaty. Its fragments are indeterminate blunt-edged. It exhibits rarely testaceous or prismatic distinct concretions. It is commonly of moderate hardness and easily frangible. It gives a blood-red streak and is apt to stain the fingers. Sp. gr. 3.42 to 3.76.

It acquires a dark tinge before the blowpipe but is infusible either by itself or with borax, to which however it gives an olive-green colour. Its constituent parts, according to Lampadius,

are	Oxyd of iron	- - -	65.4
	Silex	- - -	20.7
	Alumine	- - -	9.3
	Oxyd of manganese	- - -	2.7
			98.1

It occurs in beds and veins usually with red hæmatite and red ochre, also with quartz, hornstone and red jasper. It is met with in various parts of Germany (the crystallized varieties come from Oberhals in Bohemia) in Norway, Siberia and in considerable quantities in Lancashire. It affords good cast iron, and pretty malleable though somewhat soft bar iron.

4. *Subsp.* Red Hæmatite. *Rother Glaskopf*, Wern. *Hématite rouge*, Broch.

Its colour is intermediate between brownish red and steel-grey, sometimes it passes into blood-red and bluish-grey. It occurs in mass, also of particular shapes, such as reniform, botryoidal, stalactitical and globular. Its external lustre is casual; internally, it is usually glistening, with a semi-metallic lustre. Its fracture is stria fibrous either delicate or coarse; parallel, radiating or in bundles. Its fragments are

wedged-shaped, sometimes in the coarse fibrous variety, splintery. It occurs almost always in distinct concretions either large or small granular or curved lamellar. It gives a blood-red streak; is hard, brittle, and generally stains the fingers. Sp. gr. 4.84 to 5.0.

It has not yet been analysed with any accuracy, but from the results in the large way it contains about 60 per cent. of iron, and is the richest of the whole species. It occurs in the same situations with the preceding subspecies in veins, beds and rock masses in primitive transition and floetz mountains. It affords excellent iron both cast and malleable: most of the plate-iron and iron wire of England is made from it. When ground to a fine powder it is largely employed as a polishing material by most workers in metal.

It is particularly abundant in Lancashire, in the Forest of Dean in Gloucestershire, in Devonshire and in Saxony, but is scarcely at all to be met with in Norway, Sweden, Poland, Hungary and Russia.

Sp. 7. BROWN IRONSTONE. *Braun Eisenstein*, Wern.

This like the former is to be divided into four subspecies.

1. *Subsp.* Brown scaly iron ore. *Brauner Eisenrahm*, Wern. *Eisenrahm brun*, Broch.

Its colour is intermediate between steel-grey and clove-brown. It occurs seldom in mass, disseminated or globular, but more frequently superficial and frothy, sometimes also irregularly dendritical. It has a considerable metallic lustre. Its fracture is small lamellar passing into compact. It is very soft and almost friable; stains the fingers, is somewhat unctuous to the touch; is light so as sometimes to float on water.

It blackens before the blowpipe but does not melt, it tinges glass of borax of a yellowish-green colour. It has not been analysed.

It occurs lining cavities in brown hæmatite.

2. *Subsp.* Brown Iron ochre. *Ockricker Brauneisenstein*, Wern. *Ocre de fer brune*, Broch.

Its colour is light yellowish brown, inclining to ochre-yellow and clove-brown. It occurs in mass and disseminated. It is destitute of lustre; has an earthy fracture; its fragments are indeterminate blunt edged. It is tender, passing into friable; soils the fingers, and is heavy.

It has not been analysed. It becomes black by ignition, whence it is distinguished from yellow earth which burns red. It accompanies brown hæmatite.

3. *Subsp.* Compact brown Ironstone. *Dichter*

Brauneisenstein, Wern. *Mine de fer brune compacte*, Broch.

Its colour is clove-brown. It occurs massive and disseminated, also of particular shapes, such as cylindrical, stalactitic, reniform, cellular, with pyramidal impressions and rarely in pseudomorphous cubes, rhombs, and lenses. It also forms the substance of several petrefactions, especially of madreporites, corallites and fungites. Internally it is dull or faintly glimmering. Its fracture is usually even, sometimes large and flat conchoidal, also fine grained uneven, and earthy. Its fragments are indeterminate blunt edged. Its streak is yellowish-brown passing into ochre-yellow. It is moderately hard, and easily frangible. Sp. gr. 3.5 to 3.75.

Before the blowpipe it becomes black and magnetic. It accompanies brown hæmatite.

4. *Subsp.* Brown Hæmatite. *Brauner Glaskopf*, Wern. *Hematite brune*, Broch.

The colour of the recent fracture is clove brown passing into steel-grey, blackish brown and brownish-black, or rarely into yellowish brown and ochre yellow. The external surface tarnishes to black, bluish-black, tombac brown, bronze and gold-yellow: it also often presents bright iridescent metallic colours. It occurs sometimes in mass, but more commonly stalactitic, coralliform, botryoidal, reniform, tuberous, cylindric, cellular, dendritic, and in pseudomorphous six-sided pyramids. Its surface is smooth or granular, rarely drusy, and is shining. Internally it is only glistening with a lustre between pearly and resinous. The fracture of the clove-brown varieties is long and delicately fibrous; of those that incline to blue, short and coarse fibrous; of the black, very delicately fibrous passing into conchoidal; of the blackish brown, radiated; the fibres are generally more or less diverging. The fragments are splintery or wedged-shaped, sometimes indeterminately angular. It occurs in lamellar and granular distinct concretions, sometimes each concretion is granular externally and lamellar in its cross-fracture. It is commonly opaque; the brownish black is slightly translucent on the edges. Its streak is yellowish-brown; it is moderately hard, brittle, and easily frangible. Sp. gr. 3.95.

It blackens before the blowpipe and gives an olive-green colour to borax. It has not been analysed; but in the smelting furnace affords from 40 to 60 per cent. of iron.

Brown ironstone occurs in the newer of the primitive mountains, but more frequently in transition and floetz mountains; it is found in

veins, beds and rock masses, and is accompanied by black ironstone, spathose ironstone, brown spar, calcareous and heavy spars. It passes on one hand into red ironstone and on the other into spathose ironstone.

It melts easily and for the most part without a flux; when one is required argillaceous schist is generally made use of. The cast iron which it affords is not equal to that from red ironstone; but the bar iron is both very malleable and hard, probably from the manganese which it contains: hence it yields excellent steel. It occurs in great abundance in Saxony, Bohemia and other parts of Germany, also in Tyrol, Carinthia, Stiria, Piedmont, and the South of France. It is scarcely at all to be met with in Norway, Sweden or Russia; it is found in Cornwall, and occasionally in other parts of Britain, but not in sufficient abundance to be wrought.

Sp. 8. SPATHOSE IRONSTONE. *Spatheisenstein*, Wern. *Fer spathique*, Broch.

Its colour is greyish yellow, passing into Isabella yellow and greenish-grey; it is also found hair and clove-brown and brownish-black. It occurs in mass, disseminated, with pyramidal impressions and very often crystallized. The forms of its crystals are the following.

1. A perfect rhomboid with plane or convex faces.

2. The same, with the obtuse angles deeply truncated.

3. The lens, either regular or turned up at the edges in form of a saddle.

4. An octohedron with plane or convex faces and sometimes truncated on the angles.

The crystals are usually middle-sized or small. The surface of the octohedron is smooth and specular; of the other crystals drusy and rough. Internally it is more or less shining with a lustre between pearly and vitreous. Its fracture is foliated, with straight or curved lamellæ: it is divisible in three directions crossing each other obliquely. Its fragments are rhomboidal. It generally presents granular distinct concretions. The light coloured varieties are translucent either entirely or at least at the edges, those of a deep colour are opaque; the former give a greyish-white streak, the latter a yellowish-brown one. It is harder than calcareous spar, and easily frangible. Sp. gr. 3.6 to 3.8.

Before the blowpipe it becomes black and magnetic but does not melt; with borax it forms a spongy dirty yellow mass: it effervesces slowly with acids. Specimens from Sweden and Stiria

have been analysed by Bergman¹ with the following results.

	Stirian.	Swedish.
Oxyd of iron - -	38	22
Oxyd of manganese	24	28
Carbonat of lime -	38	50
	100	100

100 parts of the Stirian afforded by fusion with borax in a lined crucible 42 parts of a silvery white regulus.

It occurs in veins in primitive mountains accompanying lead, silver, and copper ores. In floetz mountains it forms beds, and is accompanied by brown iron ore, brown spar, and calcareous spar.

It is found in small quantities in Britain and the North of Europe, and is sufficiently abundant to be manufactured chiefly in the following places. At Schmalkalden in Hesse is a bed of the black variety 25 fathoms thick, which has been worked for several centuries. In Westphalia the light coloured is prodigiously abundant. At Eisenerz in Stiria, Hüttenberg in Carinthia, Jauberling in Carniola, and Schwatz in the Tyrol, are large founderies supplied by this ore. At Somorostro in Biscay is an entire hill composed of this species.

The iron obtained from this ore is particularly valuable, as it may be converted into excellent steel immediately from the state of cast iron; the bar iron formed from it is both hard and tough.

Sp. 9. BLACK IRONSTONE. *Schwarz Eisenstein*, Wern. *Mine de Fer noire*, Broch.

Of this there are two subspecies.

1. Subsp. Compact black ironstone. *Dichter Schwarzeisenstein*, Wern.

Its colour is between bluish-black and steel-grey. It occurs in mass, tuberous, reniform, botryoidal, &c. Its internal lustre is glimmering, semimetallic. Its fracture is conchoidal passing into fine-grained uneven. Its fragments are indeterminately angular. It forms thin and concentric curved lamellar concretions. It is moderately hard, brittle, and easily frangible. Sp. gr. 4.07.

It occurs in primitive and floetz mountains accompanied by brown ironstone, spathose ironstone and quartz. It is a rare mineral and appears to have been found only in Saxony, the Upper Palatinate, Hesse and some other parts of Germany.

It is easily fusible and yields a good iron, but

corrodes the sides of the furnace. It was long confounded with the compact grey manganese.

2. Subsp. Black Hæmatite. *Schwarzer Glaskopf*, Wern.

This differs from the preceding in the following particulars. Its colour inclines more to a steel-grey. Its fracture is very delicately fibrous passing into even: the fibres are either curved or strait, bundled or diverging round a centre. The fragments are wedge-shaped. It occurs in coarse-grained distinct concretions. It has hitherto been found only at Schmalkalden in Hesse.

Sp. 10. ARGILLACEOUS IRONSTONE. *Thoneisenstein*, Wern.

In this are comprehended the seven following subspecies.

1. Subsp. Reddle or Red chalk. *Roethel*, Wern. *Crayon rouge*, Broch.

Its colour is light-brownish red passing into cherry red. It occurs only in mass. Its principal fracture is fine-slaty and glimmering; its cross fracture is fine earthy and dull. Its fragments are commonly tabular, also splintery or indeterminate. The colour of its streak is similar to that of the mineral in mass, but is somewhat lighter and more shining. It soils the fingers, and may be used to write with. It may readily be cut with a knife, is easily frangible, adheres strongly to the tongue, is soft but meagre to the feel. Sp. gr. 3.1 to 3.9.

When exposed to a red heat it decrepitates and becomes black: at a high heat it melts into a greenish-grey frothy enamel.

It occurs generally in the newer argillite, forming entire beds or large imbedded masses.

In Silesia it is said to be found in compact limestone.

It is found in various parts of Germany, but is principally wrought at Thalitter in Hesse. It is never smelted for the iron that it contains, but is largely used for drawing and marking: the coarser varieties are employed by the carpenter and the finer by the painter. What are vulgarly called *Red-lead pencils* are composed of thin slips of the finer kinds of reddle inclosed in a wooden case.

2. Subsp. Columnar argillaceous Ironstone. *Stanglicher Thoneisenstein*, Wern. *Fer argilleux scapiforme*, Broch.

Its colour varies between liver-brown and cherry-red. It occurs in mass and in globular and angular pieces. It is dull, and has a fine earthy fracture. It forms columnar distinct concretions either thick or thin, strait or curved,

¹ Ess. ii. p. 230.

parallel or diverging, sometimes they are articulated. The surface of the concretions is rough and dull. Its streak is blood-red or yellowish brown. It is soft, brittle, very easily frangible; adheres to the tongue, is meagre and somewhat rough to the touch, and moderately heavy.

It blackens before the blowpipe, effervesces with borax, and communicates to it an olive-green colour.

It is found in beds of shale, and seems in many cases to be a pseudo-volcanic product, being accompanied by porcellanite and burnt clay.

It occurs in the Upper Palatinate, in Bohemia and other parts of Germany, and has been found by Jameson in the Isle of Arran. It is by no means a common mineral, and is scarcely ever employed as an ore of iron.

3. *Subsp.* Lenticular argillaceous Ironstone. *Linzenformiger Thoneisenstein*, Wern. *Fer argilleux lenticulaire*, Broch.

Its colour is reddish or yellowish-brown, brownish-red, and greyish-black. It occurs in masses. Its lustre is glistening, strongly semi-metallic. Its fracture is uneven passing into thin flaty. Its fragments are indeterminately angular blunt-edged. It occurs in small and round granular or in compressed lenticular distinct concretions; these last are considered by many authors as actual petrefactions. It gives a slightly-shining streak, not materially differing in colour from the entire mineral. It is soft, brittle and easily frangible. The black variety is often magnetical.

According to Lampadius it consists of

Oxyd of iron	-	-	64.
Alumine	-	-	23.
Silex	-	-	7.5
Water	-	-	5.

99.5

The red variety, which is commonly in lenticular distinct concretions, occurs in rock masses in transition mountains. The brown and black varieties, which are in granular distinct concretions occur in beds between the variegated sandstone and the most recent shell-limestone.

The red and brown varieties abound in various part of the European continent, the black has hitherto been only found in the canton of Berne.

The red affords excellent cast iron, the brown affords both bar and cast iron of a good quality; the black gives a large quantity of iron, but of a bad quality, and is difficult of reduction.

4. *Subsp.* Jaspery argillaceous Ironstone. *Jaspifartiger Thoneisenstein*, Wern.

Its colour is brownish-red. It occurs in masses; it is internally feebly glimmering. Its fracture is flat-conchoidal passing into even. Its fragments approach more or less to the cubical form. It is moderately hard, brittle and easily frangible. The shape of its fragments, and the general resemblance of its external appearance to common jasper, distinguish it from the other subspecies.

It occurs between Vienna and Hungary in a large bed.

5. *Subsp.* Common argillaceous Ironstone. *Gemeiner Thoneisenstein*, Wern. *Fer argilleux commune*, Broch.

Its usual colour is yellowish or bluish-grey, or steel-grey; frequently also yellowish or reddish brown; these colours alter much by exposure to the air and become in general deeper, nor does this change take place at the surface alone but penetrates frequently through the whole mass. It occurs in masses or disseminated, sometimes also cellular, and containing impressions of shells and vegetables. Internally it is dull. Its fracture is commonly earthy, sometimes fine-grained uneven, or flat-conchoidal, or flaty. Its fragments are indeterminate. It has for the most part only a very moderate degree of hardness. It is brittle; easily frangible; adheres a little to the tongue; is meagre to the feel. Sp. gr. 2.93 to 3.47.

It blackens before the blowpipe, and gives with borax a blackish-green glass.

It appears to consist essentially of oxyd of iron, alumine and a little silex; there is also a small variable proportion of pyrites dispersed through it. The amount of iron which it yields in the large way varies between 30 and 40 per cent.

It occurs in beds in floetz mountains; especially in the independent coal-formation and the newest floetz-trap. The large establishments at Carron in Scotland, Coalbrookdale in England, Merthyr Tydvil in South Wales, &c. are principally supplied by this ore.

It bears a considerable resemblance to compact limestone and indurated clay, but is distinguished from them by its superior specific gravity and perfect opacity.

6. *Subsp.* Nodular Ironstone. *Lapis Etites*. *Eisenniere*, Wern. *Fer reniforme*, Broch.

Its colour is yellowish-brown of various degrees of intensity: internally the colour is lighter and it often incloses an ochre-yellow kernel. It occurs in roundish masses from the

size of a walnut to that of a man's head. Its fracture is even towards the surface and fine-earthly towards the centre. The external layers are semi-metallic and glimmering, but towards the centre it is dull. The fragments are indeterminate. It occurs in lamellar concentric distinct concretions, often inclosing a loose kernel. The exterior layers are soft, the internal are very soft, almost friable. It is brittle, easily frangible, adheres to the tongue. Sp. gr. 2.57.

It occurs imbedded in ferruginous clay in the most recent floetz mountains, also in the floetz-trap and coal formations. It yields an iron of fine quality and is largely manufactured both in England and Scotland, especially at the places mentioned under the last subspecies.

7. *Subsp.* Pea shaped, or Pisiform, Ironstone. *Bohnerz*, Wern. *Fer Pisiforme*, Broch.

Its external colour is accidental and is yellowish, reddish or greyish: internally it is yellowish-brown passing into blackish brown. It occurs in small round grains, sometimes spherical, sometimes slightly compressed. Its surface is rough and dull: internally it is dull at the centre, but acquires gradually a glistening resinous lustre in proportion to the distance from the centre. Its fracture is fine-earthly at the centre, but even towards the surface. It occurs in thin concentric lamellar distinct concretions; gives a yellowish-brown streak, is soft, not very brittle, but easily frangible.

According to an analysis by Vauquelin, it contains

Iron	- - -	30
Oxygen	- - -	18
Alumine	- - -	31
Silex	- - -	15
Water	- - -	6

100

It occurs in cavities in secondary floetz limestone, the grains being concreted together by calcareous stalactite: it also occurs in beds of clay, and in flat beds immediately beneath the surface.

It occurs in various parts of Germany, Switzerland, France, and Dalmatia.

Its produce of metal varies from 30 to 40 per cent. it supplies very considerable ironworks at Arau near Berne, and the greater part of the French iron is said by Brochant to be produced from this ore.

Sp. 11. BOG IRON-ORE. *Rasen Eisenstein*, Wern. *Mine de Fer de gazon*, Broch.

Of this there are the three following subspecies.

1. *Subsp.* Morafs ore. *Morasterz*, Wern. *Mine des Marais*, Broch.

Its colour is yellowish-brown. It occurs sometimes in the state of friable earthy particles, sometimes in mass, or tuberos or carious. It is dull both externally and internally: its fracture is earthy: it stains the fingers, is fine-grained but meagre to the feel; and moderately heavy.

2. *Subsp.* Swamp ore. *Sumpferz*, Wern. *Mines des Lieux bourbeux*, Broch.

Its colour is dark yellowish-brown, passing into dark yellowish-grey. It occurs in amorphous masses, also tubercular and carious. Internally it is dull, but the darker varieties are glimmering. Its fracture is earthy, passing into fine-grained uneven. It gives a clear yellowish-brown streak; is very soft, brittle, and easily frangible. Sp. gr. 2.94.

3. *Subsp.* Meadow ore. *Wiesenerz*, Wern. *Mine des prairies*, Broch.

Its colour is internally between blackish and yellowish-brown; in the clefts it exhibits a bluish-black and steel-grey tinge. It occurs massive, in rounded lumps, perforated, and tuberos. It is internally shining or glistening, with a resinous lustre. Its fracture is minute conchoidal or earthy, or even, or fine-grained uneven. It gives a yellowish-brown streak; is soft, brittle, and easily frangible.

All the preceding subspecies belong to the same formation and appear to be the most recent of any of the ores of iron. They are probably formed by deposition from water which has become charged with iron by means either of carbonic acid or the vegetable acid that is generated in mosses and marshes. The meadow ore is the oldest and the morafs ore the newest.

It occurs in Britain and various other parts of the North and East of Europe. It yields from 30 to 36 per cent. of iron, well fitted for the finest kinds of cast ware. For wire or plate iron it is not qualified, on account of its being more or less cold-short, which is supposed to arise from a mixture of phosphoric acid. The usual flux employed in smelting it is limestone; it is also often mixed with red or brown ochre or hæmatite, by which the fusion of each is facilitated, and the produce improved both in quantity and quality.

Sp. 12. BLUE MARTIAL EARTH. *Blaue Eisenerde*, Wern. *Fer terreux bleu*, Broch.

Its colour when recently dug is said to be white, but it afterwards acquires an indigo-blue or smalt-blue, or various degrees of intensity. It occurs in mass, disseminated or investing, but

always in dull pulverulent particles, more or less cohering. It stains the fingers, is meagre to the touch, and moderately heavy.

Before the blowpipe it becomes of a reddish-brown and then melts into a black shining globule, attractable by the magnet. It tinges glass of borax brown, which at length becomes dark yellow. It is readily soluble in acids.

It has been supposed by some to be native Prussian blue, and by others to contain phosphoric acid, but its analysis by Vauquelin discovered nothing except iron, alumine, and lime.

It occurs in nests in beds of clay, and disseminated in bog iron ore, or investing peat.

Sp. 13. GREEN MARTIAL EARTH. *Grüne Eisenerde*, Wern. *Fer terreux vert*, Broch.

Its colour is yellowish or olive-green. It occurs generally friable and superficial; rarely in mass, disseminated or carious. Internally it is dull. Its fracture is fine-grained earthy, sometimes uneven. It stains the fingers, is very soft, meagre to the touch, easily frangible, and moderately heavy.

Before the blowpipe it becomes first red, then of a deep brown, but does not melt *per se*. It tinges borax of a greenish-yellow colour. It has been mistaken for bismuth or nickel ochre, but appears to contain no other metallic substance except iron.

It occurs at Braunsdorf and Schneeberg in Saxony, in veins.

Sp. 14. ARSENIAT OF IRON. *Wurfelerz*, Wern.

Its colour is dark brownish green, or brownish yellow. It occurs in mass and crystallized in cubes, either perfect or with the solid angles replaced by equilateral triangular planes. The planes of the crystals are smooth and shining. Internally it is glistening, with a vitreous lustre.

Its fracture is imperfectly foliated; its fragments are indeterminate. It is translucent; is a little harder than calcareous spar, and brittle. Sp. gr. 3. By decomposition it acquires a deep brownish-red colour, and at length becomes pulverulent.

Before the blowpipe it melts and gives out arsenical fumes. Its component parts, according to Chenevix, are

Arsenic acid	- - -	31.
Oxyd of iron	- - -	45.5
Oxyd of copper	- - -	9.
Silex	- - -	4.
Water	- - -	10.5
		100.0

The copper and silex appear to be entirely casual, for an analysis by Vauquelin presented the following results.

Arsenic acid	- - -	18.
Oxyd of iron	- - -	48.
Water	- - -	32.
Carbonat of lime	- - -	2

100

It has been found hitherto only in veins in Carrarach, Tincroft, and Muttrel mines in Cornwall.

§ 2. Analysis and Assay of Iron ores.

1. The experiments on which Mr. Howard and Proust have founded their analyses of the meteoric native iron have been related in the preceding section. A method to the full as compendious and more satisfactory may however be deduced from Klaproth's very valuable analysis of chrysoprase.^m (a) Let the iron be dissolved in moderately strong nitric acid, (b) then add liquid and perfectly caustic ammonia to super-saturation: after digesting the mixture a little while in a heat lower than that of boiling water, pour off the fluid part and repeat the digestion with ammonia as long as this latter acquires a blue colour. The insoluble portion is oxyd of iron, (c) which may either be heated with a little wax in a covered crucible and thus reduced to the state of magnetic oxyd, of which 100 parts indicate 73 of metallic iron; or it may be mixed with a little nitric acid and kept for a few minutes in an open crucible at a low red heat, by which it will be changed to the perfect red oxyd, of which 100 parts indicate 52. of iron. The ammoniacal solution contains the nickel, the amount of which may be thus estimated. (d) Saturate the ammonia with nitric acid and decompose the green solution thus produced by pure prussiat of potash: a sea-green precipitate will be thrown down, which when ignited in a covered crucible becomes entirely attractable by the magnet, and of which ignited residue 3 parts indicate 1 of metallic nickel.

In order to analyse the proper native iron, the best way of proceeding appears to be, (a) to dissolve the whole in dilute nitric acid; (b) then to separate the lead in the state of sulphat by sulphat of soda, and afterwards (c) by means of caustic fixed alkali at a boiling heat to throw down the mixed oxyds of iron and copper, from which the latter may be subsequently extracted by means of caustic ammonia.

2. Pyrites is magnetical or unmagnetical; if

^m Analyt. Eff. i. p. 420.

the former, it may be either proper magnetical pyrites or common pyrites mixed with magnetic iron either in the metallic state or in that of black oxyd. Muriatic acid will ascertain to which of these three divisions any particular specimen belongs. If the magnetism is owing to black oxyd dispersed through common pyrites, muriatic acid will not produce any inflammable gas by digestion with it; if the specimen is a mixture of metallic iron and pyrites, the gas will be simple hydrogen: but if the substance under examination is magnetic pyrites, the gas will be sulphuretted hydrogen.

Both species of pyrites are most conveniently analysed in the following way. (a) The pyrites being previously reduced to a very subtle powder, is to be digested in moderately strong nitric acid and boiled almost to dryness, a fresh portion of acid is then to be added, and this process is to be repeated till the whole of the sulphur is converted into sulphuric acid. (b) The liquor being poured off, and the undissolved residue being thoroughly edulcorated, the washings are to be added to the liquor. (c) Into this is to be dropped a slight excess of carbonat of soda; and the precipitate, if there should be any, is to be separated. (d) The residual liquor, being perfectly neutralized by a little nitrous acid, is to be decomposed by muriat of barytes added as long as any precipitate takes place. This precipitate is sulphat of barytes, of which 100 parts indicate 14.5 of sulphur in the ore. (e) The insoluble residue (b) is to be digested with caustic soda, evaporated to dryness and slightly ignited, the precipitate (c) being then added, the whole is to be dissolved in muriatic acid and boiled nearly to dryness, the affusion of water will then leave the filix in the state of a white insoluble powder. (f) The muriatic solution being mixed to a slight excess with ammonia, the alumine and oxyd of iron will be precipitated together leaving the lime, if any happens to be present, in solution, whence it may be procured in the state of carbonat by any mild alkali. (g) Lastly, the iron and alumine are to be separated either by boiling in nitric acid, which will dissolve the earth and leave the metallic oxyd untouched, or by digestion in caustic soda or potash, which will produce a similar effect.

3. *Magnetical Ironstone, Specular Iron ore, and Red Ironstone*, as far as they have been examined, appear to be composed of oxyd of iron with a small casual quantity of filix and alumine. They are for the most part with difficulty and imperfectly acted on by acids alone;

the best method of proceeding in their analyses is therefore the following. (a) Let the ore be reduced to a very fine powder and heated in a silver crucible with liquid caustic soda; when the whole of the moisture is evaporated, let the remaining matter be ignited to a low degree for a few minutes; then dissolve the whole contents of the crucible in dilute muriatic acid and evaporate the solution nearly to dryness; boil the residue in distilled water sharpened with a little muriatic acid, and the filix will remain behind undissolved. (b) The solution being reduced to a moderately small compass, add caustic soda to a slight excess and boil it upon the precipitate thus produced: the precipitate when edulcorated is pure oxyd of iron; which may be reduced to the magnetic state and then estimated, as we have already mentioned in paragraph 1 of the present section. (c) The alkaline solution contains the alumine, which may be separated by muriated ammonia, and then washed and ignited.

Black Ironstone and Brown Ironstone, as to composition, differ from the preceding only in containing manganese, the same method of analysis may therefore be applied to these as to the former, with this difference, that as the precipitate (b) will in this case be a mixture of the oxyds of iron and manganese, an additional process will be requisite to separate them. This may be effected with considerable exactness by dissolving the mixed oxyds in muriatic acid and adding to the hot solution caustic soda drop by drop till the liquor becomes colourless, or till the precipitate that falls down at each addition of alkali begins to be white; thus the oxyd of iron will be thrown down and the manganese will remain in solution, which latter may be procured after the removal of the iron by continuing to add soda till no further precipitate is occasioned. Another and equally exact method of separating these two oxyds is by adding to the muriatic solution succinat of soda, which precipitates the iron but does not affect the manganese.

4. *Spathose Ironstone* may contain carbonic acid, the oxyds of iron and manganese; lime, magnesia and barytes probably in the state of carbonat, a little filix and alumine. It may conveniently be analysed in the following way. (a) Being reduced to extremely fine powder let it be digested in muriatic acid with a little nitric acid, a slow effervescence will take place and the carbonic acid may be estimated by the loss of weight, or more exactly by collecting the gas in a mercurial pneumatic apparatus, and

then separating the carbonic acid by limewater. (b) The portion of the ore that is insoluble in the muriatic acid digested two or three times upon it is filex. (c) The muriatic solutions and washings being mixed are to be concentrated by evaporation and decomposed at a boiling heat by caustic soda in excess: (d) the precipitate and supernatant fluid being boiled together for a short time the alumine alone will be dissolved. (e) The insoluble portion being well washed is to be ignited and abstracted once with nitric acid, by which the lime, barytes and magnesia will be dissolved, and the oxyds of iron and manganese will remain behind. (f) These oxyds may be separated by digesting the mixture at a very gentle heat with dilute nitric acid and a small piece of sugar, the manganese will be totally taken up and the remaining pure oxyd of iron may be brought to the magnetic state by being heated with wax. (g) The nitrat of manganese of the foregoing process being mixed with carbonated soda a precipitate takes place, which after washing and drying at a heat below redness, is pure carbonat of manganese, of which 100 parts indicate 55. of reguline manganese. (h) The nitric solution of process (e) being considerably diluted with water, is to have sulphuric acid dropped in as long as any precipitate is formed, this is sulphat of barytes; which being removed, the other earths are to be thrown down by a carbonated alkali; are to be again dissolved in dilute sulphuric acid, and the sulphats of lime and magnesia thus produced being precipitated by alcohol are finally to be separated from each other by cold water, which will dissolve out the sulphat of magnesia without taking up any considerable quantity of the other.

5. The *argillaceous* and *bog ores*, the *blue* and *green martial earths*, contain a part or the whole of the following substances, viz. oxyds of iron and manganese, phosphat of iron, filex, alumine, and lime. These may be separated in this manner. (a) Having pulverized and ignited the ore, abstract it twice or thrice with nitric acid; then pour off the acid and wash the residue with a little more strong nitric acid: (b) add these acids together and evaporate almost to dryness. Then wash the residue with cold water and the phosphat of iron will remain behind. (c) Ignite the insoluble residue of (a) with caustic soda and separate the filex in the usual way by muriatic acid. (d) Mix together the nitric and muriatic liquors and boil them with an excess of caustic soda, the alumine will be taken up and the metallic oxyds and lime will be precipi-

tated. (e) This compound precipitate being ignited and abstracted with nitric acid, the lime will be dissolved out; and nothing being now left but the oxyds of iron and manganese, these may be separated according to process (f) of the preceding paragraph, or by either of the methods described at the end of par. 3.

6. The *Arseniat of Iron*, though it consists essentially only of arsenic acid and iron, also contains accidentally filex and copper. It is conveniently and expeditiously analysed by Mr. Chenevix^b in the following manner. The ore being pulverized and exposed to less than a red heat loses its water of crystallization. The residue being boiled with caustic potash, the alkaline solution is to be separated by filtration, and neutralized with nitric acid: being then treated with nitrat of lead, a precipitate of arseniat of lead takes place, of which 100 parts indicate 33 of arsenic acid. To the residue insoluble in potash muriatic acid is to be added, which will take up the iron and copper, leaving the filex behind. The muriatic solution being then supersaturated by ammonia, the oxyd of iron is precipitated, and the oxyd of copper is retained in solution by the alkali.

Having shewn the method to be pursued in the *analysis* of the various species of iron ores, we now proceed to treat of the method of *assaying* them, which for practical purposes is sufficiently accurate and even more satisfactory than a regular analysis. The three first and the three last species are never employed by the manufacturer of iron, the eight intermediate ores therefore are all that we have at present any concern with.

The ancient metallurgists, such as Cramer, Gellert and others, recommend the use of very active saline fluxes in the assay of iron ores; for this however there seems no sort of necessity, as the high degree of heat which is absolutely required to bring the metallic part of the ore into fusion will also vitrify the earthy parts by the assistance of lime and bottle glass, without having recourse to borax or any alkaline salt.

The richest varieties of the magnetic iron-stone, especially the iron-sand, may be assayed by mixing them when finely pulverized with about $\frac{1}{2}$ of charcoal or twice the quantity of fine sawdust and subjecting the mixture in a covered crucible to the full action of a powerful wind furnace for about an hour: the iron will be found collected into a somewhat irregular button beneath a small quantity of cellular scorix. This very simple mode of proceeding however

^b Phil. Transf. for 1801, p. 220.

can only be had recourse to when the proportion of earthy matter in the ore is very small, and even then it will be better to add to the materials some green bottle glass, finely pounded, in weight equal to about one-half of the ore. The common magnetic ironstone contains a considerable proportion of earth, chiefly silica, and may be most effectually and easily assayed by means of the following reducing flux. For every 8 parts of ore take 8 of bottle glass, 6 of limestone or chalk, and 1 of charcoal: mix the whole accurately together along with the ore, and heat it for a full hour in a wind furnace. If the operation has been properly conducted the iron will be found in the form of a well defined button, covered by a compact vitreous slag nearly of the colour of common green glass.

The specular iron ore generally contains a portion of sulphur from the casual admixture of pyrites; it must therefore be roasted at a moderate red heat as long as any sulphureous odour is perceptible, after which, being mixed with 8 parts of bottle glass, 6 of chalk, and $1\frac{1}{2}$ of charcoal to 8 of the ore, it is to be fused as already mentioned.

The red, brown and black ironstones may be treated as the preceding.

The spathose ironstone requires no roasting, and is best assayed by reducing it to powder and placing it in a crucible, lined with a mixture of charcoal and a little clay, and then covering it with $\frac{1}{4}$ of its weight of calcined borax.

The argillaceous and bog ores after roasting may be mixed with 8 parts of bottle-glass, 7 of chalk, and $1\frac{1}{2}$ of charcoal to 8 of ore, and fused in an unlined crucible; diminishing the proportion of chalk in those varieties that contain a considerable quantity of calcareous earth.

§ 3. *Reduction of the Ores of Iron.*

The ancient and modern methods of extracting iron from its ores differing very materially from each other, it will be necessary to treat of them separately.

Iron as it exists in the ore, whether in a state of greater or less oxydation, is capable of being brought to the metallic state when heated in contact with charcoal, by a much lower temperature than is required for its actual fusion, and the iron being brought to this state, the earthy matter with which it is mixed may be vitrified by the addition of a proper flux, so as to allow the particles of metallic iron to subside in consequence of their superior specific gravity

to the bottom of the mass, although they are only in that soft pasty state which common bar iron exhibits when it is at a white heat. Now the blowing machines of the ancient metallurgists being greatly inferior to those which are employed at present, they were obliged to make use only of the richest and most easily reducible ores, and even these they were never able properly speaking to fuse in quantity, so that *cast iron* was a modification of this metal wholly unknown to them.

That iron which was esteemed the best was prepared in the following manner.^a A mass of brickwork was raised 5 feet in length and breadth and $3\frac{1}{2}$ feet high, resembling a smith's hearth, except that in the middle of this was sunk a cup-shaped cavity or crucible, one foot in depth and half a foot wide, in the upper part of which was made a hole opening into a channel through the brick work. This hole being closed with clay, the crucible was filled with lighted charcoal heaped up so as to be above the level of the hearth; a blast of air was then admitted through a pipe let into the wall in the same manner as a smith's forge, and so contrived that the focus of the blast should be just above the centre of the crucible. Charcoal alone was added from time to time, till the heap became thoroughly hot, and then at the discretion of the workmen the ore, in very small pieces, unroasted but mixed with unslacked quick-lime, was laid on alternately with the charcoal. As soon as it had descended low enough to be within the immediate influence of the blast (which in a furnace of this construction would be in a few minutes) the lime and earthy part of the ore became fused into a slag and enveloping the iron now in a metallic state, sunk down into the crucible, displacing the charcoal with which it had been at first charged. The matter remaining at rest in the crucible gave an opportunity to the particles of iron to sink to the bottom, which they did in greater or less proportion according to the fluidity of the slag and the completely metallic state of the iron. After this process had been going on for the space of from eight to twelve hours, the crucible became filled with melted matter: at this time the hole which had been at first stopped up with clay was opened by means of an iron bar introduced through the channel in the brick-work, and the scoriae immediately flowed out, leaving the iron behind covered with hot charcoal. The blast being stopped, the furnace soon got sufficiently cool to allow the workmen

^a Agricola de re Metall. p. 337.

to take out the iron, which was found imperfectly concreted together into a mass nearly of the shape of a wooden bowl: this being transferred to an anvil was first carefully hammered with wooden mallets to break off the encrusting scoriæ and render it sufficiently compact to bear the tilt hammer, to which it was next subjected: being then divided into five or six pieces, each was separately forged into a bar, and thus the operation was finished. The iron thus obtained was extremely tough and hard but difficult to work, and was in great request for helmets and other articles of defensive armour, and in general for all purposes where toughness and hardness united were particularly required. The rich quality of the ore and the circumstances in which it was reduced were probably the chief causes of the excellence of this kind of iron; a peculiarity however in the method of forging it may also have somewhat contributed to this; for while it was under the tilt-hammer, an assistant stood by with a ladle of water, with which he sprinkled the bar as often as it was struck by the hammer.

The poorer ores which were incapable of being smelted in the above method, were first picked, washed and roasted, then reduced to pieces no larger than hazle-nuts, and reduced (no doubt with the addition of lime) in blast furnaces from seven to eight feet high and shaped like a chimney. In these a considerably greater heat could be produced than in the former, but it does not appear that the metal when taken out of the furnace was in the state of cast iron; certain it is that it was always allowed to cool there and was never run into pigs as is the modern practice.

Some ores that are very rich and yield a soft iron have been occasionally wrought in a manner still more simple than either of the proceeding. The rich specular ore of the island of Elba in particular, appears formerly to have been worked to a considerable extent in this, which if not the earliest is certainly the rudest method that has hitherto been devised. The ore being broken into small pieces is heaped upon a bed of charcoal in a very simple reverberatory furnace. When the whole has been glowing hot for some time, the pieces being now soft and at a welding heat, are by the dexterous management of the workmen brought in close contact with each other by means of an iron bar; they are then lightly hammered while still in the furnace, and thus the whole mass acquires sufficient compactness

to be removed to the anvil without falling to pieces; it is now hammered with a gradually increasing force, the earthy impurities are thrown off together with the scales of black oxyd, the lump is divided into pieces of a convenient size, which by repeated heating and hammering are drawn into bars. The rich red hæmatite, as appears from an experiment of Mr. Musket, is capable of being manufactured in the same way.

These ancient methods have gone into disuse, not because the quality of the iron thus produced was to be objected to, but because the time and fuel consumed were enormous, and the iron that remained in the scoriæ amounted at least to one half of the original metallic contents of the ore.

The modern methods of reducing the ores of iron are principally two; depending on the nature of the fuel made use of. In England and Scotland the fuel is for the most part coak; but in the rest of Europe, charcoal: and the processes in the founderies where the latter is employed being the most simple, we shall commence with this method.

The best Swedish bar iron, named in the market Oregrund iron, from the port whence it is shipped for the English market, is entirely prepared from the magnetic ironstone of Dannemora. The forges and founderies where it is manufactured are those of Soderfors and other places in the province of Roslagia, and the most approved processes that it undergoes for this purpose are the following.*

The ore in moderately large pieces, such as it comes from the mine, is first roasted. For this purpose an oblong coffer of masonry, eighteen feet long, fifteen wide and about six in depth, open at top and furnished with a door at one of its smaller extremities, is entirely filled with logs of wood, over this the ore is piled to the height of from five to seven feet, and is covered with a coating of small charcoal almost a foot and a half in thickness. Fire is then communicated to the bottom of the pile by means of the door just mentioned, and in a short time the combustion spreads through the whole mass: the small quantity of the pyrites that the ore contains is decomposed by the volatilization of the sulphur, the moisture is also driven off, and the ore from being very hard and refractory becomes pretty easily pulverizable. In the space of twenty-four hours the roasting is completed, and the ore when sufficiently cool is transferred to a stamping-mill,

* Jars Voyages Metallurg. i. p. 127.

where it is pounded dry, and afterwards sifted through a network of iron, which will not admit any piece larger than a hazle nut to pass. It is now ready to be smelted.

The smelting-furnace is a strong quadrangular pile of masonry, the internal cavity of which though simple in form is not very easily described: it may be considered however in general as representing two irregular truncated cones joined base to base: of these the lower is scarcely more than one-third of the length of the upper, and is pierced by two openings, through the upper of which the blast of wind from the blowing machine is admitted into the furnace, and from the lower the melted matter, both scoriæ and metal, is discharged from time to time at the pleasure of the workmen. The furnace is first filled with charcoal alone and well heated, after which alternate charges are added of ore, either alone, or mixed with limestone if it requires any flux, and charcoal: the blast is let on and the metal in the ore being highly carbonized in its passage through the upper part of the furnace is readily melted as soon as it arrives in the focus of the blast, whence it subsides in a fluid state to the bottom of the furnace covered with a melted slag. Part of the clay that closes the lower aperture of the furnace is occasionally removed to allow the scoriæ to flow out, and at the end of every ninth hour the iron itself is discharged into a bed of sand where it forms from ten to twelve small pigs. As soon as the iron has flowed out the aperture is closed again, and thus the furnace is kept in incessant activity during the first six months in the year; the other six months are employed in repairing the furnaces, making charcoal and collecting the requisite provision of wood and ore.

The next process towards the conversion of pig into bar iron is refining. For this purpose a furnace is made use of resembling a smith's hearth, with a sloping cavity sunk from ten to twelve inches below the level of the blast-pipe. This cavity is filled with charcoal and scoriæ, and on the side opposite to the blast-pipe is laid a pig of cast iron well covered with hot fuel. The blast is then let in and the pig of iron being placed in the very focus of the heat soon begins to melt, and as it liquefies runs down into the cavity below; here being out of the direct influence of the blast it becomes solid, and is then taken out and replaced in its former position, the cavity being again filled with charcoal; it is thus fused a second time, and after that a third time, the whole of these three pro-

cesses being usually effected in between three and four hours. As soon as the iron has become solid it is taken out and very slightly hammered to free it from the adhering scoriæ; it is then returned to the furnace and is placed in a corner out of the way of the blast and well covered with charcoal, where it remains till by farther gradual cooling it becomes sufficiently compact to bear the tilt-hammer. Here it is well beaten till the scoriæ are forced out, and is then divided into several pieces, which by a repetition of heating and hammering are drawn into bars, and in this state it is ready for sale. The proportion of pig iron obtained from a given quantity of ore is subject to considerable variation from a difference in the metallic contents of different parcels of ore and other circumstances, but the amount of bar iron that a given weight of pig-metal is expected to yield is regulated very strictly, the workmen being expected to furnish 4 parts of the former for 5 of the latter, so that the loss does not exceed 20 per cent.

The method of preparing bar iron in all the other countries of Europe where charcoal is the fuel made use of, is upon the whole very similar to that which we have just detailed, allowing for a few variations according to the different species of ore that are employed. But in Great Britain the number of charcoal furnaces is trifling compared with those where coak is used, and the adoption of this kind of fuel has led by necessity to a method of manufacturing iron, quite peculiar to this country, and wholly inapplicable to those establishments that are carried on by means of charcoal. Each method has its peculiar advantages and disadvantages; for if in quantity of produce from each forge the British claims the superiority, yet this is probably more than counterbalanced by the inferior quality of the metal, the greater multiplicity of apparatus, and consequently the larger capital laid out, and the smaller proportion of iron procured from a given weight of ore. The method, however, pursued by the British manufacturers is not a matter of choice, but has been forced upon them by the deficiency of wood. They must either almost entirely abandon this important branch of metallurgy, or substitute coak with all its inconveniences to charcoal. Thus circumstanced, much skill and ingenuity has been employed by them in overcoming the peculiar difficulties with which they have had to contend, and in making the most of the peculiar advantages connected with this mode of working, and upon the whole with so much success as to enable the British manufactured iron to enter into competition

with every other kind except the very best Norwegian and Swedish.

The common and nodular argillaceous ironstone are the prevailing kinds of ore made use of in the coak smelting works, partly because these are really better fitted, with this fuel, to produce iron of a good quality than the rich hæmatites of Lancashire, Cumberland and Devonshire, and partly because this kind of ore being usually found to accompany the seams of coal, it may be procured at little expence, and the same situation that is well adapted for a supply of fuel is equally convenient for abundance of ore.

The first process that the ironstone undergoes after it has been broken into pieces not larger than an egg, is roasting. This is sometimes performed in cup-shaped kilns, the bottom being occupied by lighted coals and the kiln then filled up with ore, which by the time that the fuel is consumed is found to be sufficiently torried. The most usual way however of burning ironstones is the following. Upon an oblong piece of firm and level ground is laid a bed of small coal from four to eight inches in thickness; upon this is placed a stratum of ironstone composed of pieces as nearly as possible of the same size, and from 18 inches to two feet thick: the upper surface of this is then rendered more compact by filling up the interstices with smaller pieces of ore. Upon this rests a layer of small coal not more than two inches thick, and on this as a base, is reared a gradually diminishing pile of ore so as to resemble the ridge of a house; finally, the whole external surface receives a compleat covering of small coals and coal dust. The pile is kindled by applying burning coals to the lower stratum, which by degrees ignite the whole mass. The breadth of the pile at the bottom varies from 10 to 16 feet, the usual height is about five feet, and the length varies from 30 feet to 60 yards. When the coals are consumed the pile gradually cools, and in eight or ten days may be wheeled away to the furnace.*

The ore if well roasted will now be of a reddish brown colour, of diminished specific gravity and will have become magnetical, the sulphur, water, inflammable matter, and carbonic acid that it originally contained, will have been dissipated, and it is now ready to be smelted.

The furnace resembles externally a truncated quadrilateral pyramid of considerable height in proportion to its thickness, it is built of the strongest masonry, with contrivances to obviate

the danger of its cracking by the expansion that takes place when it is heated. The interior of the furnace consists of the five following parts, reckoning from the bottom upwards.

First the *hearth*, composed of a single block of quartz grit about two feet square: upon this is erected what in France and Germany is called the *crucible*, which is a four-sided cavity six feet six inches high, slightly enlarging upwards so as to be two feet six inches square at the top: the part above, called the *boshes* is in the shape of a funnel or inverted cone, eight feet in perpendicular height, and twelve feet in diameter at the top; this terminates in the *cavity* of the furnace which is of a conical figure, thirty feet high, and three feet diameter at the top; from this part it enlarges into a funnel shaped *chimney* about eight feet high and sixteen in diameter at its mouth. The lining from the hearth to the top of the boshes is composed of large blocks of quartz grit, and that of the cavity of the furnace is formed of fire bricks 13 inches long, and three inches thick. About two feet above the hearth is a round aperture called the *Tuyere*, made in one of the sides of the crucible to admit the extremity of the blast pipe, through which the air in a high state of compression is forced into the furnace; and at the bottom of the crucible is an aperture through which the scoriæ and melted metal are from time to time discharged. A furnace of this construction, if it meets with no accident, may be kept in constant work for three years or more without requiring any repairs.

The furnace is charged at the chimney by regular intervals with coak, iron ore, and limestone in the proportion of about 4 of the first, $3\frac{1}{2}$ of the second, and 1 of the third, by weight, care being taken so to regulate the frequency of the charges, as that the furnace shall be always full nearly to the top of the great cavity. The density of the blast and the form of the discharging pipe are ordered so that the chief focus of heat is about the bottom of the boshes; hence the ore has to descend about 38 feet perpendicular, before it arrives at the place where the fusion is effected. This does not happen in less than 48 hours, so that the ore is all this time in a state of cementation at a high temperature in contact with the burning fuel, and in consequence is almost saturated with carbon when it reaches the hottest part of the furnace. Being arrived at this place, the limestone flux, and the earthy particles of the

* Mueset in Phil. Mag. iii. p. 205.

coaks and ore run down into a slag, the iron is also melted and more or less decarbonized, and in part oxydated by the blast inversely according to the proportion of fuel with which it is mixed (for the oxygen of the air by preference unites with the loose carbon of the coaks, rather than with that which has combined with the iron). The fluid mass soon sinks down below the influence of the blast, and while it remains in quiet at the bottom of the furnace the globules of iron are precipitated from the slag in which they were enveloped, and occupy the lowest place, while the covering of scorix thus interposed between the metal and that portion of the blast which is reflected downwards, prevents it from suffering any further loss of carbon. In proportion as the melted matter accumulates, the slag being the uppermost, flows out at the aperture made for this purpose, and the iron is let out at regular intervals into furrows made in sand, where it forms what is called pig iron, or into a large reservoir whence it is poured by means of ladles into moulds, forming all the various articles of cast iron ware, from cannons and steam engine cylinders, to fire grates and common iron pots.

The great object of the manufacturer is, with a given quantity of fuel to obtain as large an amount as possible of highly carburetted cast iron, as this is the kind which bears the highest price in the market: but as from various causes the iron is generally found to be more or less decarburetted, it becomes a matter of considerable importance to ascertain by external characters the principal changes induced by a progressive diminution of carbon in order that the value of any particular sample may be correctly and expeditiously ascertained. By long and careful observation it has been found sufficient for all practical purposes to arrange the several kinds of cast iron under one or other of the four following subspecies.

1. *Smooth faced Iron*, or No. 1. of the manufacturers. This seems to be composed of iron nearly saturated with carbon, and mixed with a comparatively small proportion of oxyd and earthy impurities. Its upper surface is smooth and convex, entirely free from oxyd, and often covered with a thin crust of plumbago: it presents a coarse granular fracture with a brilliant metallic lustre and a dark blue colour.

2. *Good melting pig Iron*, or No. 2 of the manufacturers. This differs from the preceding in containing probably a smaller portion of carbon and a larger admixture of oxyd of iron. Its upper surface is slightly convex and full of small cavities: its fracture is coarse granular towards

the centre of the pig, but the concretions manifestly diminish in size as they are situated nearer the surface; its colour is dark-grey inclining to blue.

3. *Grey Iron*, or No. 3 of the manufacturers. In this the amount of carbon is still further diminished. Its upper surface is level, sometimes slightly concave, and presents more and larger cavities than the preceding, it is slightly oxydated superficially; its fracture is fine granular, and its colour is light grey.

4. *White Iron, forge pigs, ballast Iron*. In this the quantity of combined carbon is smaller and the admixed oxyd larger than in any of the preceding. Its upper surface is concave, rough, and covered with a plate of oxyd; its fracture is compact sometimes tending to striated, its colour is tin-white, occasionally mottled with grey.

We shall now proceed to state in a general way, the circumstances in the smelting which principally influence the quality of the produce. Much depends on the fuel: if the coaks are not perfectly made but retain a part of their bitumen, the whole mass cakes together in the upper part of the furnace, and instead of descending regularly to the focus of heat, falls down by pieces, and at irregular intervals, so that part of the metal is detained too long before the blast, and in consequence is decarbonized and oxydated, while other portions pass so rapidly through the furnace as never to be thoroughly reduced, hence the amount of the produce is diminished and its quality greatly deteriorated. Nor is it of less importance that the coak should be perfectly dry when put into the furnace, otherwise the water which it contains will be decomposed, the hydrogen and part of the oxygen will dissolve their respective portions of carbon, and escape in a gaseous state, while the remainder of the oxygen will combine with the iron; which will thus be injured, not merely by the privation of carbon, but the positive addition of oxygen. It is further requisite that the proportion of fuel be adapted to the richness of the ore, so that there may be sufficient both to keep up the necessary degree of heat as well as to carbonize the metal: hence as the charges of ore and fuel are always proportioned by measure, if an ore somewhat richer than usual happens accidentally to be employed without a corresponding addition of fuel, the produce though somewhat increased in quantity, will be more than equivalently reduced in quality. Another circumstance that the manufacturer must carefully attend to, is the proper choice of ore with regard to fusibility, for as it is not only requisite that the iron

should be melted, but also highly carbonized, and as coak gives off its carbon with much more difficulty than charcoal does, it is manifest that a very fusible ore would melt long before it arrived at the focus of the furnace, and passing rapidly through, would reach the hearth without having had time to imbibe the proper quantity of carbon. Hence it is that the rich hæmatites, although they afford an excellent quality of iron when smelted with charcoal, produce nothing but white iron when treated in the coak furnace; while on the other hand argillaceous ironstone being much more refractory, does not melt till it comes into the very hottest part of the furnace, and therefore has had full time to absorb the desirable quantity of carbon. Another thing to be attended to is the proper regulation of the blast, and this depends upon its dryness, its temperature, its compression, and its direction. The dryness and temperature appear to be principally governed by the season of the year, and therefore are but little capable of being modified by the manufacturer. It is plain that the dryer and colder the air is, the greater will be its effect on the combustion, and it is found by constant experience, that the produce of iron during the summer months is greatly inferior in quantity, and materially so in quality to that which is manufactured in the winter: a clear dry and severe frost is the most favourable period in every respect for the working of the furnace, and a change to snow or rain is infallibly followed by a corresponding deterioration. The higher the temperature of the blast is when it is delivered into the furnace, the smaller (the degree of compression and other circumstances being equal) will be the quantity of oxygen contained in every cubic foot, and of course the vigour of the combustion. Nor is the force of the blast and its direction a subject of less importance; it is obvious that in proportion as the charge descends, the carbonaceous matter is continually diminishing, hence the proper situation for the focus of the blast is that part of the furnace, where, when the ore shall have arrived it will be fully carbonized and surrounded with a sufficient quantity of fuel to excite an intense heat, and absorb nearly the whole of the oxygen of the air, and thus prevent it from either oxidating the iron, or carrying off the carbon with which it may be combined. This precise situation, in a furnace properly constructed, will be found to be just within the expansion of the boshes; but as this is more than four feet above

the tuyere hole, the blast must be delivered with great velocity and in a direction somewhat slanting upwards, in order that it may be reflected by the opposite wall of the crucible, and arrive at its proper place without undergoing any material decomposition. When the blast enters too rapidly, and in too concentrated a state, it renders the line of its passage before it is reflected so cool, that the descending slag which comes within its influence is suddenly solidified, and blown into a tube reaching perhaps half way across the crucible through which the blast continues to rush, and in consequence of this protection, is conveyed with greater precision, and in a less decomposed state into the upper part of the furnace. If after this the compression of the air is somewhat diminished, the tube still remains firm, often for days together, and the furnace works in the best manner. But on the other hand, when too loose and soft a blast is admitted, and more especially if it is charged with moisture, it is unable to reach the top of the crucible without being decomposed, and the reflection which it undergoes from the wall of the crucible, weakens and disperses it to such degree, that the combustion which ought to take place within the boshes, now occupies the whole upper part of the crucible: in consequence of this, the tube of scoriæ is presently burnt away, the iron almost as fast as it is melted is ignited and oxydized, the tuyere hole glows like the sun with an intensely vivid white light; the scoria from being yellowish white streaked with blue, becomes green, brown, and finally black, nearly the whole of the iron in the state of oxyd being taken up by it; the blocks of refractory gritstone with which the lower part of the furnace is lined are worn into great holes, and in the space of a few hours prodigious damage is sustained.

There has been no regular analysis of cast iron, but from the phenomena that take place during its conversion into bar iron, which we shall proceed to describe, it will be sufficiently apparent what are its principal constituent parts.

One of the most obvious differences between cast and bar iron, is the brittleness of the former and the malleability of the latter: this malleability has accordingly been adopted by the manufacturer as the essential character of bar iron, and as affording him a mode by which to judge of the efficacy of the means employed by him in reducing crude to malleable iron.

The first step in the process is refining^d. For

^d Collier in Manchester Trans.

this purpose the pigs are smelted in a refinery, (the construction of which we have already noticed) by means of charcoal; and as soon as the metal is in fusion it is let out into a mould of sand to separate the scoriæ that rise to its surface, and in this state is called a *half bloom*. As soon as it has become solid it is again transferred to the furnace and treated as before. Sometimes even a third fusion is required before the iron shows sufficient malleability to clot into lumps when broken down almost at a fusing heat, by an iron bar. When it has acquired this consistency, it is taken out in moderate sized pieces, which being placed under the great forge or *springing* hammer, are speedily stamped into cakes about an inch in thickness. Several piles of these cakes about a foot high, are then laid on flat circular stones, and placed in the *baling* or reverberatory furnace, where they are strongly heated. As soon as the whole acquires a pasty state, one of the piles is taken out by a workman and drawn under the hammer into a short bar: which being finished, is applied to another of the piles, to which it presently adheres: being then withdrawn, the new portion is welded firmly to the first by means of the hammer, and thus the bar is doubled in length; by repeating the same simple and ingenious operation the bar is made as long as its weight will conveniently allow. The cracks in the bar are then closed, and its tenacity is improved by heating it afresh in a fire made of coal, called the *chaffery*, (*chaufferie* Fr.) and again subjecting it to the action of the forge-hammer. It is now in the state of common bar iron, and ought to be entirely free from all earthy particles. After this, according to the use for which it is intended, it is transferred to the slitting mill; where it is laminated and cut up into bars and rods of various dimensions, by which its toughness and compactness is much improved, and is then ready for the smith.

The above method is called *stamping*; but besides this, there is another known by the name of *flourishing*, which requires a short notice. In this the pigs of cast iron when put into the refinery are kept for about two hours and a half in a pasty state without actually melting, and at the end of this period the metal is taken out by shovels and laid on the open floor on a plate of cast iron where it is beaten with hand-hammers in order to knock off the cinders and other adhering impurities. It is afterwards placed under the forge hammer and beaten, at first gently, till the whole mass has

acquired some tenacity, and then the middle part is drawn into a bar four feet long, terminated at each extremity by a cubical lump of rough iron: in this state it is called an *Ancony*. It is now taken to the Chaffery, hammered afresh, and the ends being also drawn down to the same dimensions as the other part, the bar is completed.

A third method of working iron, called *puddling*, was invented by Mr. Cort, (as appears from the specifications of his two patents^e) and is we understand coming into general use at Sheffield and other places. It is particularly characterised by combining the reverberatory with the finery furnace, and the whole process is managed in the following manner. The pigs of cast iron produced by the smelting furnace are broken into pieces, and are mixed in such proportions according to their degree of carbonization, that the result of the whole shall be a grey metal. This mixture is then speedily run down in a blast furnace, where it remains a sufficient time to allow the greater part of the scoriæ to rise to the surface. The furnace is now tapped, and the metal runs into moulds of sand, by which it is formed into pigs about half the size of those which are made at the smelting furnace: and these pigs when cold are broken into pieces.

A common reverberatory furnace heated by coal, is now charged with about $2\frac{1}{2}$ cwt. of this half refined grey iron. In a little more than half an hour, the metal will be found to be nearly melted; at this period the flame is turned off, a little water is sprinkled over it, and a workman by introducing an iron bar, or an instrument shaped like a hoe, through a hole in the side of the furnace, begins to stir the half fluid mass and divide it into small pieces. In the course of about fifty minutes from the commencement of the process, the iron will have been reduced by constant stirring to the consistence of small gravel, and will be considerably cooled. The flame is then turned on again, the workman continuing to stir the metal, and in three minutes time the whole mass becomes soft and semifluid, upon which the flame is again turned off. The hottest part of the iron now begins to heave and swell, and emit a deep-blue lambent flame, which appearance is called fermentation: the heaving motion and accompanying flame soon spreads over the whole, and the heat of the metal seems to be rather increased than diminished for the next quarter of an hour: after this period the tem-

perature again falls, the blue flame is less vigorous, and in a little more than a quarter of an hour the metal is cooled to a dull red, and the jets of flame are rare and faint. During the whole of the fermentation, the stirring is continued, by which the iron is at length brought to the consistency of sand, it also approaches nearer to the malleable state, and in consequence adheres less than at first to the tool with which it is stirred. During the next half hour the flame is turned off and on several times, a stronger fermentation takes place, and a loud hissing noise is perceived, the lambent flame also becomes of a clearer and lighter blue; the metal begins to clot and becomes much less fusible and more tenacious than at first; the fermentation then by degrees subsides, the emission of blue flame nearly ceases, the iron is gathered into lumps and beaten with a heavy-headed tool. Finally, the tools are withdrawn, the apertures through which they were worked are closed, and the flame is turned on in full force for six or eight minutes. The pieces being thus brought to a high welding heat are withdrawn and shingled; after this they are again heated and passed through grooved rollers, by which the scoriæ are separated and the bars thus forcibly compressed acquire a high degree of tenacity.

The more welding and hammering that bar iron is subject to, the tougher it becomes and the more fibrous, or nervous as the French term it, is the fracture. Hence arises the superiority of *Stub iron* to all the other varieties for barrels of fowling pieces and other uses where extreme toughness is required. It is prepared in the following method. A moderately broad ring of the best Swedish iron is placed horizontally and filled with old horseshoe nails (called stubs) set perpendicularly, till it can hold no more; a pointed bar of iron is then driven into the centre of the circle, and thus locks the whole fast together. A welding heat is then applied, and the mass is hammered very gently at first, till the nails and ring become completely united: it is then drawn down into bars and affords an iron of peculiar closeness, toughness, and malleability.

§ 4. *Manufacture and properties of Steel.*

Steel combines the fusibility of cast iron with the malleability of bar iron, and further possesses this very valuable property, that when heated and suddenly cooled, it becomes intensely hard, and is therefore much superior to simple iron

for all kinds of cutting instruments, files and various other tools. In the present section we shall describe the different methods of preparing and tempering steel, reserving for the next section an enquiry into the chemical composition of this useful substance.

The most ancient way of making steel is probably that related by Agricola.^a Take some highly carburetted bar iron, cut it into small pieces and mix it with pulverized scoriæ, put the mixture into a crucible lined with charcoal, and bring it to a state of fusion in a blast furnace. When both the iron and scoriæ are thoroughly fluid, immerse in this metallic bath four lumps of bar iron, weighing about thirty pounds each, and let them remain in this situation during five or six hours, stirring the bath occasionally with an iron rod; by this time they will have become soft and spongy, upon which they are to be taken out and drawn down into bars by the forge hammer. As soon as this is performed, the bars still hot, are to be plunged into cold water, by which they will be rendered brittle, and are then to be broken under the hammer into short pieces. The crucible in the mean time is to be replenished with the same mixture as before, and when its contents are become quite fluid, the pieces into which the bars have been broken are to be again immersed till they become soft: each piece being then taken out and forged separately into a slender bar, is to be cooled while yet glowing hot, in cold water, and the process is finished. The above method is we believe entirely obsolete, though with a few modifications that are sufficiently obvious, it would in all probability be found highly advantageous.

The *native* steel of Eisenhartz in Stiria has always been in high estimation since the eighth century, and is prepared directly from the ore nearly in the same manner as common bar iron.^b The ore made use of is the Spathose Ironstone, consisting of the carbonats of iron, manganese and lime, together with a mixture of clay: it is procured in vast abundance from the neighbouring hill of Arzberg, and care is taken not to use any that has not been exposed for several years to the action of the air. No flux of any kind is necessary, and the fuel, which is charcoal, does not on an average exceed in weight one fifth of the ore. When a sufficient quantity of melted matter is collected at the bottom of the furnace it is let out into a deep mould, where it remains quiet a few minutes to allow the scoriæ

^a Beddoes in Phil. Transf. lxxxii. p. 173.

^b De Re. metall. p. 344.

^c Jars voyages metallurg. l.

Rambourg in Journ. des mines, No. 88 and 89. Hassenfratz in An. de Chim. xix. p. 22.

to rise to the surface: this being done, a little water is sprinkled over it, which hardens the scoriæ and renders them easily removable: a second but much thinner crust of scoriæ generally succeeds, which is got rid of in the same manner. A little water is now thrown on the melted metal itself, by which its surface is suddenly covered with a congealed crust about an inch thick; this is removed, and by repetitions of the same process the greater part of the mass is thus converted into these irregular plates: what remains is a mass in the state of half malleable iron. These plates are transferred to the crucible of a refinery which has been previously lined with charcoal, and are covered with scoriæ and brought to a state of fusion, carefully observing however not to direct the blast from the bellows into the crucible, lest the iron should be decarbonized. After the whole has been in quiet fusion for some time, the fire is slackened, and as soon as the metal has congealed the scoriæ still fluid are let off. The mass is then subjected to a second fusion in the refinery with the same precautions as at first, and is now sufficiently purified to be forged: it is accordingly extended under the hammer and cut into bars which are examined by their fracture, and separated according to their qualities, into hard steel, soft steel, and steely iron: the latter is reserved by itself and used for pointing plowshares and other coarse work; but the others are made up into packets, observing to place the hardest steel on the inside, which are then drawn into bars at a lower heat than that required for iron, and then the process is complete. Thus the whole art consists in purifying the cast iron, taking at the same time particular care that the carbon which it contains is not burnt away. If the original cast iron is very highly carbonized it sometimes happens that the steel retains too large a proportion of carbon, which is evinced in the refinery by its being more easily fusible, and requiring a longer time to become solid again than usual: this defect however is speedily remedied by adding iron filings or scraps of bar iron, the quantity of which is regulated by the degree of fusibility to be corrected.

If the manufacturer wishes to procure iron from this ore instead of steel, the only difference required in the treatment is to get rid of nearly the whole of the combined carbon by roasting the plates in a reverberatory furnace before they are brought to the refinery, and by avoiding to line the crucible of the refinery with pounded

charcoal. The iron thus produced is of an excellent quality.

The best of the Swedish and Norwegian ores are occasionally wrought into steel of a very good quality by nearly the same process of manufacture, provided in the smelting a larger proportion than usual of charcoal has been employed to ensure a highly carbonized metal.

The usual method of converting iron into steel is by *cementation*¹. For the purposes of manufacture, this is performed on large quantities at a time in the following manner. A cementation or converting furnace consists of two parallel troughs, constructed of fire-brick, sufficiently long to admit with convenience a common bar of iron; these troughs rest upon a long grate from which flues proceed so as to distribute the heat as evenly as possible to every part: an arched vault is thrown over the top, and the whole is inclosed within a cone of masonry as the glass house furnaces are. The bars of iron intended for cementation are of the very best quality, (in England none but the Swedish Oreground iron is employed for this purpose) and are carefully examined to ascertain that they are quite free from cracks, flaws, and every appearance indicative of their not being completely malleable. The requisite selection being made, a stratum of coarsely bruised charcoal is laid at the bottom of the cementing trough, upon which is arranged a layer of iron bars: to this succeeds another of charcoal, and so on till the trough is nearly filled, observing that the upper as well as the lowest layer is charcoal: it is then covered with a mixture of hard rammed clay and sand in order to exclude the air. A trough thus charged will contain from seven to ten tons of iron. The fire being lighted, the heat passes into the flues and raises the temperature of the troughs to a glowing red which is maintained for the space of from seven to eleven days, according to the quantity of iron. At the extremity of each trough is a small hole, through which two or three bars project a few inches in order that they may be occasionally withdrawn to ascertain the progress of cementation: when by the trial bars, it appears to be complete, the fire is put out, and after the troughs are sufficiently cool they are emptied of their contents. The form of the bars thus converted, remains unaltered, but their surface is covered over with bubbles or blisters, whence the steel in this state is called *blister steel*: it is heavier than the iron from which it was made on account of its having absorbed a portion of carbon from the

¹ Collier in Manch. Trans. V. p. 122.

charcoal with which it was in contact, though this is by no means the only action that takes place in the process of steel-making, as we shall show in the next section. Blister steel is employed only for the coarsest purposes, such as pointing horses shoes, ploughs, and other agricultural instruments, &c. By being drawn down into smaller bars under the tilt-hammer, its texture is considerably improved, and it is known in the markets by the name of *tilted steel*. As repeated hammering improves iron, so it does steel: hence if a bar of highly carbonized blister steel is broken into very short pieces, and these being formed into small packets, are again welded together and drawn down into bars, which being again doubled together are welded and tilted, repeating the process two or three times, the result will be a very material improvement in compactness and toughness, and the metal will be found well qualified for swords and the larger articles of cutlery: this steel has long been prepared in high perfection in Germany, whence it is called *German steel*; it is also known by the name of *shear steel*.

This is the proper place to mention the process of *case-hardening*, which in fact is only an imperfect kind of cementation, converting little else than the immediate surface of the metal into steel, and therefore being performed not on the rough bar but the manufactured article. The cements or carbonaceous substances used on this occasion are bone shavings or turnings, horn cuttings, and old leather shoes. The work intended to be cased having been previously filed to the requisite shape, that there may be as little occasion as possible to apply the file afterwards, is laid together with the cement in a pan of plate-iron. A forge fire is then made of considerable size, and when the upper part has caked together it is carefully lifted off without breaking, the pan is laid upon the red coals and covered with the caked mass. In this state it remains for nearly two hours, without urging the fire. Small pieces of iron wire that have been previously introduced into the pan being withdrawn from time to time, are dipped while hot in cold water, and by the file and the character of the fracture, the progress of the cementation is determined. When the intended degree of carburation is obtained, the fire is increased and the articles as soon as sufficiently heated are taken out of the pan and plunged in cold water. The inferior kinds of table-knives and some surgical instruments, where a con-

siderable degree both of toughness and hardness is required, are prepared in this way.^k

The finest kind of steel however, called *English cast steel*, yet remains to be mentioned. It is commonly prepared by breaking to pieces the blister steel and then melting it in a crucible with a flux composed of carbonaceous and vitreifiable ingredients. When thoroughly fused it is cast into ingots, which by gentle heating and careful hammering are tilted into bars. By this process the steel becomes more highly carbonized in proportion to the quantity of flux, and in consequence is more brittle and fusible than before; it is inferior to the other kinds of steel in being incapable of welding either with iron or steel, but on the other hand surpasses them all in uniformity of texture, hardness, and closeness of grain, hence it is the material of all the finest articles of English cutlery. The composition of the flux used in preparing this steel is kept a secret among a few manufacturers, and in consequence various experiments have been instituted both here and elsewhere to discover either the same or an equally successful method of making this beautiful substance. In 1795, Clouet published the results of some valuable experiments, from which it appears that by simply fusing bar iron with charcoal a cast steel may be obtained more or less carburetted, according to the proportion of charcoal employed, and therefore possessing at pleasure in a greater or less degree the qualities of fusibility, brittleness and hardness: he also showed that the same effects may be produced by fusing bar iron with glass and charcoal, or the black oxyd of iron with the requisite proportion of charcoal alone, or by keeping in fusion for about the space of an hour a mixture of small bits of iron and equal parts of clay and marble or any other calcareous carbonat.^l In 1800 Mr. Mushet took out a patent for preparing cast steel of various qualities by fusing bar iron with different proportions of charcoal, coinciding for the most part with the facts and principles before laid down by Clouet, and confirmed by his own experiments;^m but whether the steel thus prepared is equal to the finest cast steel of Huntsman, has not we believe been as yet completely ascertained.

Steel is rendered hard by heating and then suddenly cooling it. The degree of hardness which it is capable of acquiring is in direct proportion to its fusibility, or in other words to the quantity of carbon with which it is combined; and the degree of hardness which in

* For the above and some other practical information contained in this article, the Authors are indebted to the professional liberality of Mr. W. H. Pepsy. ^l Journal des Mines, No. 49. ^m Repertory, xiv. p. 176.

any particular instance is actually given to it is in proportion to the difference of temperature between the medium in which it is heated and that in which it is cooled; modified however by the capacity for heat and the conducting power of the cooling medium. Thus if steel is heated somewhat below the degree at which it melts and then transferred into oil at the temperature of 200° , the hardness thus acquired will be inferior to that which would have been obtained if water, or still more so if mercury, at the same temperature had been made use of. Again, if instead of oil at 200° the same fluid at 40° had been employed, a greatly superior degree of hardness would have been produced.

The hardness acquired by this method has generally been thus accounted for. The particles of the metal by being heated are placed at a greater distance from each other than before, and in proportion as this heat is again abstracted, the attraction subsisting between them will become efficacious, and they will approach nearer to actual contact; but the impetus with which this takes place will be in proportion to the difference of temperature, and therefore when red-hot steel is plunged in ice-cold mercury, the force or resilient spring of its particles will be greater than if mercury at 200° had been made use of, and consequently its hardness will also be greater. But this theory however ingenious is opposed by certain facts which perhaps may be found more consonant with the following explanation of them.

If we take the specific gravity of a piece of steel both when hardened and after it has been softened by heating again and gradually cooling, we shall find that its bulk in the former case is greater than in the latter, whereas if the hardness of steel was owing to the rapidity and energy with which its particles collapsed on cooling, directly the reverse of this ought to take place, the state of greatest hardness should be that of the greatest specific gravity. So in like manner we find to be the case with glass; if a little of this in a melted state is dropped into cold water it will prove very hard and brittle; but if the same piece is again heated red (without however in any degree softening it) and afterwards allowed to cool gradually, its specific gravity will have very notably increased, and it will have become tough and elastic. We may therefore consider the hardening of steel to be caused by the contemporaneous expulsion of part of its heat and the fixation of its particles before they have had time to arrange themselves and contract upon each other. Hence on the

impression of any external force, the particles that are struck are not able to slide on each others surfaces, and thus distribute the impetus which they have received over the contiguous ones; or in other words the mass becomes *harder* than it was before, hence also the whole force of a blow is borne by a comparatively small number of insulated particles, and these entirely giving way before a degree of percussion that might easily be sustained by the whole when combined, thus produce the quality of *brittleness*.

If highly carburetted steel is made nearly as hot as it can bear without melting, and is then plunged in very cold water, it is apt to fly to pieces, and even if this does not take place the metal is not applicable to any use in this state of extreme hardness, for the particles are placed so far asunder that the whole has a strong tendency to become crumbly, and will not bear a fine even sharp edge. In the practice of the best manufacturers the hardening heat even for files, which are the hardest of all steel instruments, is not greater than a red visible by daylight; and all cutting and elastic instruments require to be much softer. The various degrees of hardness necessary for different articles are not however given, as might at first be supposed, by the simple process of hardening at the requisite temperature, but by the compound method of first giving to every article nearly a file hardness, and then, by the subsequent process of *tempering*, reducing the hardness to the particular degree necessary for each article.

Tempering consists in softening hardened steel by the application of a heat not greater than that which was employed in hardening it; for this purpose it is gradually heated more or less according to the temper required, and cooled again either gradually or rapidly, this making no difference, after which the steel is found to be softened or tempered exactly in proportion to the heat which it has undergone. While the steel is tempering its surface displays a succession of colours (supposed to arise from a commencing oxydation) in proportion as it becomes more and more heated, which the workmen in this metal have ingeniously taken advantage of as indicating and serving to denominate the degree of temper required for different articles. The first perceptible colour is a light straw yellow, and this being produced by a small degree of heat indicates the highest or hardest temper; to this succeeds a full yellow, then a brown, afterwards a reddish blue, then a light blue, and lastly a full deep blue passing into black, which being the other extremity of the series

denotes the lowest degree of temper and a hardness only a little superior to what the piece of steel would have acquired if when heated for the purpose of being hardened it had been allowed to cool gradually instead of being plunged into a cold liquid. The old method of tempering, and which indeed is still practised by most manufacturers, is to lay the articles on a clear coal fire, or on a hot bar, till they exhibit the requisite colour; but small articles which were to be reduced to a blue temper were commonly *blazed*, that is they were first dipped in oil or melted grease, and then held over a fire till the oil became inflamed, and thus evaporated.

Some particular articles require a nicety of temper that is not very easily attained by trusting merely to the change of colour, a circumstance that induced Mr. Hartley, in the year

1789, to take out a patent for a new and more accurate method. For this purpose a mercurial thermometer graduated as high as 600° is to be immersed in an iron trough heated by a furnace or lamp placed below it and filled with fusible metal, upon the surface of which the steel is to be laid, which may thus be tempered with great accuracy at any degree of the thermometer that the artist chuses. Oil may be substituted to the fusible metal, and the effect will be the same except that the steel being in this case tempered beneath the surface of the liquid, and of course out of the contact of atmospherical air, will not exhibit those changes of colour which take place when the other methods are employed. The following table shows the temperature at which the various colours make their appearance.

430° to 450° indicates the several tints of straw colour, and is the temper for razors and those instruments which have a stout back supporting a keen and delicate edge.

470° corresponds with the full yellow, and is the proper temper for scalpels, pen-knives, and other fine-edged instruments.

490° indicates the brown yellow, and is the proper temper for scissars and small shears.

510° indicates the first tinge of purple, and is the temper for pocket and pruning knives.

530° indicates purple, and is the temper for table and carving-knives.

550° to 560° indicates the different shades of blue, and is the temper for watch-springs, swords, and all those instruments in which great elasticity is required.

600° corresponds with black, and is the lowest degree of temper.

One great advantage attending the use of cast steel is its uniform quality: the carbon which it contains appears to be equally distributed through every part of the same mass in consequence of the fusion that it has undergone: whereas both the natural steel and the steel of cementation are apt to contain veins of iron, either quite soft or at most very slightly carburated, and thus a degree of imperfection and uncertainty is introduced extremely mortifying to the artist, and not unfrequently the occasion of much labour in vain. It is therefore no small benefit which Mr. Nicholson has conferred on the workers in iron and steel by publishing a simple and effectual method of ascertaining whether any particular bar is pure iron or steel, or a mixture of both. The surface of the metal being cleaned with a file or with emery paper, is to be spread over with very dilute nitrous acid, by which the iron will be dissolved, but the carbon will remain behind untouched; after therefore the acid has been allowed to act for a few minutes, the bar is to be put into clean water and moved about in it

gently, that both the residual acid and the nitrate of iron may be washed away, care being taken not to touch the surface with the hand or any thing else that may rub off the carbon. The bar thus washed, if pure iron, will exhibit an uniform iron-grey colour; if it is pure steel, the colour of the surface will be black, the iron having been taken up by the acid and a thin coating of carbon remaining; but if it is a mixture of iron and steel the surface will be dotted or streaked, those parts which are steel being of a dull black, and those which are iron exhibiting the usual colour and lustre of this metal.

Steel being considerably more expensive than iron, it is customary in making the larger and coarser kinds of cutting instruments to form only the edge of steel. The two bars of iron and steel are first welded together and afterwards forged into the requisite shape in the usual manner. Highly carbonized steel is however incapable of being thus united to iron, because the same temperature at which iron welds freely is that at which this kind of steel enters into fusion, and therefore the first stroke of the

hammer will entirely shatter the steel and disperse it about in small fragments. This however is a difficulty which it is well worth while taking some pains to overcome, as the efficacy and durability of instruments thus composed materially depends upon the goodness of the steel. The most effectual way hitherto discovered of uniting together iron and highly carbonized steel, is that published by Sir Thos. Frankland. The iron is to be raised to a welding heat, in one forge, and the steel is to be made as hot as it can bear without becoming very brittle, in another; both pieces are then to be quickly brought to the anvil and made to adhere together by gentle hammering.

Several curious pieces of work are made of iron and steel welded together, especially the real Damascus sword blades, which are believed to be composed of slips or thin rods of iron and steel bound together with iron wire, and the whole firmly cemented together by welding. The properties and external appearance of such a blade correspond very exactly with the supposed mode in which it is manufactured. Its colour is a dull bluish grey, it is scarcely harder than common steel from the forge, it is not easily bent, and when bent has no elasticity to recover its original figure; but the circumstance which principally characterizes it is the appearance of narrow waving lines not crossing each other and chiefly running from heel to point; they are ill-defined and about the thickness of a harpsichord wire. This wavy appearance is not produced by any perceptible indentation of the surface but merely by a slight difference in the degree of polish or brightness, and therefore may be at once distinguished from the false damasking or etching by which other sword-blades are made to resemble the genuine Damascus ones. In the false Damascus blades the waving lines, called the *water*, are obliterated by grinding, but in the real ones, although the water is at first imperceptible after grinding, yet it may at any time be made to reappear by rubbing the blade with lemon juice, no doubt on account of the unequal action of this weak acid on a surface composed both of steel and iron. °

Besides the varieties of steel that we have already described there yet remains one more, concerning which a few words will be necessary: this is Wootz.^k The substance known by this name in India, is imported into this country in the form of round flat cakes about five inches in diameter and one inch in thickness.

° Nich. Phil. Journ. 4to. i. p. 469.

When cold it is uncommonly refractory, neither breaking nor bending under the hammer. It is not nearly so easy to be filed as either bar or cast steel before these have been hardened: it takes an extremely high brilliant polish; its fracture is moderately close, resembling that of blister steel that has been heated and hammered a little. When nearly white hot it is malleable, but is much more likely to crack under this treatment than even cast steel; it requires therefore much care, labour, and time to fashion it into any required shape. When made white hot it exhibits the glassy smooth surface of welding iron, but when struck very gently with a hammer, it cracks in many places, and by a harder blow is shivered to pieces. When brought to a high heat and quenched suddenly in cold water, it becomes harder than at first, though not equally so with the finest cast steel in similar circumstances; but on the other hand, it is not capable of being sensibly softened by annealing as the other varieties of steel are. At a high heat it is fusible, and after being melted exhibits a close compact grain, is considerably brittle, and bears a very near resemblance to cast steel. From its analysis and other circumstances it is considered by Dr. Pearson as differing from steel only in containing a little oxyd of iron.

§ 5. *Comparison and analysis, of Cast Iron, Bar Iron, and Steel.*

Notwithstanding the close attention of various eminent chemists to this important subject, much yet remains to be done before an entirely satisfactory theory can be formed to account for the different properties possessed by the various kinds of iron and steel. We shall endeavour to show in the present section the progress that has already been made in this interesting analysis, and shall then point out some of the chief difficulties that yet remain to be overcome.

In all the varieties of iron and steel, the principal ingredient is metallic iron, and as this metal in the reguline state alone has the property of giving out hydrogen gas while dissolving in dilute sulphuric or muriatic acids, the amount of inflammable gas thus produced has been adopted by Bergman, by Berthollet and Pearson, as upon the whole the most satisfactory and compendious exponent of the quantity of reguline iron contained in any of the known varieties and forms of this metal. Thus a mixture of equal parts of reguline and oxydized iron by treatment with dilute sulphuric acid, will produce only half the quantity of hydrogen

^k Pearson in Phil. Transf. lxxxv. p. 322.

gas that an equal weight of pure iron would. But this can be admitted to be a perfectly accurate mode of proceeding only where the mixture thus analyzed, contains nothing that is soluble in hydrogen gas at the temperature, and in the other circumstances under which the experiment is performed. None of the kinds of manufactured iron is entirely free from carbon, and this according to Berthollet^a is taken up by the nascent hydrogen as the metal dissolves in the acid, whence originates a material source of error, the quantity of gas produced depending not merely on the proportion of iron, but also of carbon in the mixture. It appears from Berthollet's experiments that when cast iron or steel is treated by dilute sulphuric acid, at a boiling temperature, in proportion as the metal dissolves, a black spongy matter is observed floating in the solution: the quantity of this increases till the process is about half over, then

it begins to diminish, and will be found to have entirely disappeared by the time that the last portions of iron have dissolved. This black matter is carbon, which being insoluble in sulphuric acid or sulphat of iron, must necessarily have been taken up by the hydrogen. This accordingly is found to be the case, for the gas produced requires a greater proportion of oxygen for its combustion, and the result of the process is a quantity of carbonic acid. This is further confirmed by an observation of Rinman's that the inflammable gas arising from the solution of steel, affords by combustion more fixed air than that which is produced from the solution of bar iron. From the numerous experiments of Berthollet on this subject, we have selected the six following as sufficient for our purpose, and having converted the weights and measures into English, it appears that at 29.84 Bar. and 59° Fahr.

Grs.

100 of grey cast iron yield with diluted sulphuric acid	104.8 oz. measures of inflammable gas.
100 of bar iron made from the preceding - - -	111.5 do.
100 of Steel from the preceding - - - - -	108.3 do.
100 of Swedish bar iron - - - - -	114. do.
100 of Steel from the preceding - - - - -	106.7 do.
100 of white cast iron from Eisenerz - - - -	97.4 do.

It might at first be supposed that a given quantity of hydrogen would increase in bulk in proportion to the carbon taken up by it, the reverse of this however is in fact the case: therefore if Swedish bar iron be considered as the pure state of this metal, represented by the number 114, the proportion of iron contained in an equal weight of steel made from the same will be more than 106.7, because the former number indicates pure hydrogen, but the latter carburetted hydrogen.

Dr. Pearson on the other hand, in his experiments on Wootz, assures us that when dilute sulphuric acid is acting on steel at the common temperature, a quantity of black carbonaceous matter is separated, which continues to augment so as to impede the effect of the acid; if at this period a lamp is applied, the increased temperature brings on a more rapid action, and the black sediment appears rather to diminish in quantity. This diminution however Dr. P. attributes only to the solution of the iron with which the carbon was combined, and not to the solution of the carbon itself in the hydrogen: for, says he, the gas when burnt with oxygen procured from manganese, inflamed like common

hydrogen, and whether procured by means of iron, or steel, or wootz, produced only a very slight turbidness with limewater; whereas carburetted hydrogen, prepared by passing steam through hot charcoal, being treated in the same manner, rendered the limewater quite milky. The proportions of gas from iron and steel were also remarkably less than those mentioned by Berthollet. 100 grains of wootz by several experiments yielded from 78 to 84 ounce measures of gas. 100 grains of steel wire, also by various experiments, yielded from 83 to 86 ounce measures of gas. 100 grains of iron wire yielded from 86 to 88 ounce measures.

How much soever the experiments of Berthollet and Dr. Pearson differ in other respects, yet we may infer that Swedish bar iron contains a larger proportion of reguline iron than the other varieties of bar iron, that steel contains a smaller proportion than bar iron, that wootz contains a still smaller proportion, that grey cast iron is inferior in this respect to steel, and that white cast iron is the least pure of any.

We also learn that the lower the temperature is at which the solution of the iron is made, the purer is the hydrogen that is produced, and with

^a Mem. de l'Acad. for. 1786. p. 164.

proper care that the objections raised by Berthollet to the accuracy of this mode of proceeding, may be compleatly done away.

We have already mentioned that almost all the known varieties of iron and steel contain a larger or smaller proportion of carbon. The quantity of this in any particular sample of metal may best be ascertained by digesting the metal in dilute nitro-muriatic acid which will leave untouched the carbon united with a little iron. This black insoluble residue being washed in warm water and finally digested for a minute in weak ammonia, should be heated in a flask almost to redness, to expel the water and any muriat of ammonia that it may contain; being then weighed it is to be ignited in a silver or platina crucible till the whole of the carbon is burnt off, and the residual iron is oxydized: from the weight of this oxyd is to be deducted 48 per cent. on account of the oxygen, and the difference between the weight of the remainder and that of the black powder before ignition indicates the amount of carbon.

The affinity of iron for carbon is pretty considerable, though it is by no means capable of decomposing carbonic acid by combining with its base, as Musset has clearly shown in opposition to the assertion of Clouet.

The effects produced upon iron by carbon are very remarkable. First with regard to colour: the bluish grey tint of iron becomes more and more white in proportion as it combines with carbon, till it possesses almost a silvery colour and lustre, as is the case with the white cast iron, in which state the metal seems to be saturated with carbon. At the same time that these changes of colour are going on, the tendency to crystallization is rapidly increasing, hence the fracture from being fibrous and hackly, becomes first compact, then granular, and at length exhibits facets like antimony. With these changes the fusibility increases, and the faculty of welding diminishes, and soon entirely ceases: the ductility and malleability also undergo an analogous change, though not quite to so great an extent: the hardness increases, as also does the property of induration by sudden cooling, and the capability of being tempered.

Iron however may not only be saturated but supersaturated with carbon: that is to say, when at a very high temperature it will dissolve more carbon than it can hold in solution at a lower temperature; and in consequence, by slow cooling while it is still fluid, a part of this excess of

carbon will separate from the rest of the mass and rise to the surface, forming a flaky crust of plumbago or carburet of iron. Some however of the plumbago will still remain enveloped by and dispersed through the iron, giving it an uniform dark grey or black colour if the proportion is considerable, or only mottling it if the excess of this substance is very slight.

The actual proportions of carbon contained in the different kinds of iron have not yet been ascertained with any accuracy either by analysis or synthesis; but thus much appears certain, that bar iron in general contains a smaller quantity than the softer varieties of steel, and these again always contain less carbon than the common and finer cast steel; that in the white, the mottled, the grey, and the black varieties of cast iron, the dose of carbon is constantly augmenting, in the last of which the proportion of carbon is probably about $\frac{1}{8}$ of the whole.

Oxygen is also contained in most of the varieties of iron, and the effects occasioned by it in the different processes to which this metal is subjected, require more attention than has hitherto been paid to them. Cast iron appears to be highly charged with oxygen, and on this account requires to be supersaturated with carbon in order to be converted with any economy into bar iron. It may seem at first a paradox to maintain the coexistence of oxygen and carbon in the same metallic mass, especially considering the great heat to which it is exposed in the process of reduction, since it is an universal and uncontroverted fact that metallic oxyds are decomposed by carbon at a high temperature, the oxygen and carbon uniting together and being dissipated in the form of gas, the metallic regulus remaining behind. But when the roughness of the smelting process in blast furnaces, and the large quantity of materials operated on at once, as well as the great pressure of the superincumbent scoriæ are taken into consideration, we shall cease to be surprized at the apparent anomaly. The existence of oxygen in cast iron, is manifest from the phenomena that accompany the operation of *puddling* as already described in a preceding section. The crude iron being subjected to a high temperature, under a pressure no greater than that of the atmosphere, the oxygen and carbon that it contains react upon each other and produce carbonic acid and gaseous oxyd of carbon, which having escaped, the metal is found reduced to a state of malleability. The same effects take place in close vessels, as Dr. Beddoes has well shown. If

crude cast iron is put into a retort, as soon as the vessel and its contents have acquired a low red heat, an inflammable gas mixed with carbonic acid is given out with considerable rapidity (this inflammable gas must from the circumstances be the oxyd of carbon) when the production of gas ceases, the iron upon examination will be found to have lost somewhat of its weight, and to be nearly in the state of bar iron. But though this combination of the oxygen and carbon of the crude metal, and the consequent generation of air takes place with great ease when the beak of the retort is but just dipped under water, yet if the pressure amounts to five inches of water, in addition to the atmosphere, the disengagement of air proceeds very slowly, and entirely ceases if instead of the water a single half inch of mercury is employed; although upon removing this obstacle the bubbles of air pass through as before.

By the treatment that cast iron undergoes during its conversion into malleable bar iron, the greater part of the oxygen and carbon is got rid of; still however a small quantity of oxygen, the smaller in proportion to the goodness of the iron, remains. This is inferred with much probability from the blistered appearance that the bars of iron exhibit after having been converted into steel by cementation. These blisters are manifestly occasioned by the exudation of a gas from the bar, and this gas in all probability is oxyd of carbon. A further proof of the existence both of oxygen and carbon even in Swedish bar may be deduced from some interesting experiments by Mr. Mushet.* Having put some pieces of Swedish bar iron into an earthen crucible, with a flux composed of marble and calcined clay, he observed first, that the earths melted together before the iron showed signs of fusion, and that while this latter was melting, bubbles of air were continually rising from it and passing through the vitrefied flux: this gas burnt with a lambent blue flame, and probably was gaseous oxyd of carbon: the iron sustained a notable loss of weight, and had become considerably softer than at first.

Steel probably is entirely free from oxygen.

The action of vitrescent earthy mixtures comes next to be considered. It is certain that cast iron contains a very considerable proportion of scoriæ diffused through its substance, which are partly got rid of by subsequent fusion, as they rise to the surface of the metal being considerably lighter than it; while such portions as still remain are got rid of for the most part, by

hammering and laminating during the conversion of the cast iron into bar. A very small proportion of scoriæ however is not unfrequently left in the iron, as is obvious from the earthy residue that some of the varieties of this metal leave behind them when dissolved in acids. It is not yet clearly made out what is the precise effect of a little earth on the malleability of iron. Clouet has endeavoured to show† that it renders the iron softer and more malleable, but inclined to be hot short, and the experiment by which he demonstrates it is the fusing together of iron and glass, by which the effects just mentioned are produced upon the metal. But this is precisely the same experiment as that of Mr. Mushet's related in the preceding paragraph, and M. Clouet having entirely overlooked the extrication of gas from the metal, has gratuitously attributed the change produced to a combination of the iron with a little of the glass, without, as appears, taking the trouble to substantiate his hypothesis by actual analysis.

Cast iron made with coak instead of charcoal must necessarily contain a variable proportion of sulphur, nor is this substance very likely to be entirely dissipated by the subsequent refining that the metal goes through; and it appears from a direct experiment by Dr. Beddoes, that iron after being puddled and stamped, if treated with muriatic or sulphuric acid, will give out sulphuretted hydrogen. Bergman has shewn that certain varieties of iron contain manganese, and others phosphoric acid. Clouet has detected arsenic in some; and other chemists have somewhat obscurely intimated the presence of lead, copper, and zinc, which is far from improbable, as several of the ores of iron are occasionally mixed with galena, copper pyrites and blende. But the effect of these substances in small quantity on iron has not yet been ascertained by any experiments that can be depended on; it is therefore obvious how much remains to be done before we acquire a thorough knowledge, even on practical points, of this most important of all metals.

The following, in the present state of our researches on this subject, may be laid down as the essential characters of the principal forms under which iron exhibits itself. Crude cast iron besides casual impurities contains carbon, oxyd of iron, and vitrefied earth. The difference between white, mottled, grey and black cast iron depends on the proportion of carbon, which is smallest in the white and greatest in the black. By the process of refining or resmelting, most

* Tilloch's Phil. Mag. xii. p. 102, 202.

† Journ des Mines, No. 49. p. 4.

of the earth and oxyd of iron rises to the surface of the metal in the form of a dense slag; hence the residual iron differs from the crude pig-metal in containing less earth and oxyd. By the subsequent operations the carburet and oxyd of iron mutually decompose each other, forming carbonic acid and carbonous oxyd, by which the metal is freed both from its oxygen and carbon. In this state it forms bar iron, which may or may not retain a small proportion of vitrefied earth, but which seems even when purest to hold a little both of carbon and oxyd. If this bar iron is exposed in a close vessel to a high heat, the carbon and oxygen that it contains (if they are in due proportion to each other) will be entirely got rid of, the metal will become very soft, and will be at the same time malleable and fusible. If the bar iron instead of being heated by itself has access to carbon either in the state of charcoal or plumbago, its oxygen will be expelled and carbon will at the same time be absorbed: if the portion of this latter is small, the mixture will partake of the properties both of iron and steel, hence it will be very malleable and capable of being welded, but also will be harder than pure iron, somewhat more fusible and susceptible of being tempered. By being united with a fresh portion of carbon it will become still more fusible and will lose its welding property; it will become harder, more compact, and will form the fine cast steel. A further portion of carbon increases the brittleness and hardness, so as to render it incapable of being wrought, and its colour and texture will approach to that of white cast iron: in this state it may be regarded as saturated with carbon. It is however capable of uniting to this substance even to supersaturation, by which its colour and texture resembles that of grey or black cast iron; its fusibility is somewhat increased, but its hardness is so much lowered by this excess of carbon as to allow it to be wrought with ease by a common file, nor can it be materially hardened by sudden cooling or be tempered, so that it is no longer in the state of steel. By a still further cementation with charcoal it would in all probability be converted into plumbago.

Many chemists have supposed that super-carbonized steel is the same thing as crude iron, because they resemble each other in their fracture and colour and contain carbon; and upon this reasoning have been founded several imperfect and ineffectual methods of applying the finer kinds of cast iron to some of the uses of

common cast steel; but we have shown that however great may be the resemblance in some points, yet cast iron essentially differs from steel in containing both earth and oxyd of iron, and therefore cannot be substituted for it with any success.

It only remains to say a few words concerning two states of bar iron called *hot-short* and *cold-short*.

Iron that is *hot-short* or *red-short* is very soft and ductile when cold, on which account it is generally employed in the manufacture of wire; it may also be hammered and welded if treated skilfully at a full white heat, but when it has cooled down to a cherry red, it breaks away before the hammer and is dissipated almost like sand.

Cold-short iron on the contrary is harder not only than *hot-short* but also than pure Swedish bar iron; it may be wrought in the usual way when red or white hot, but possesses no toughness when cold; so that a large bar may with ease be broken across by a common hand hammer.

Hot-short iron is imagined, rather than proved, to contain arsenic, to which its brittleness at a red heat is supposed to be owing.

Cold-short iron is supposed by Bergman to derive its characteristic qualities from a portion of phosphoric acid; and it is certain that phosphat of iron has been found in iron of this description, both by the illustrious Swedish chemist just named and Meyer and Clouet.

If however it be granted that *hot-short* and *cold-short* iron respectively contain arsenic and phosphoric acid, yet it must in return be allowed that these qualities appear in very many cases where there is no reason to suspect either the one or the other, and that the methods by which these defects may be produced or remedied are in many cases at least not very reconcilable with their supposed origin.

If white cast iron, that is, such as is deficient in carbon, be exposed to the action of a current of flame after it has exhibited its proper degree of malleability, it will pass into the state of *cold-short* iron, and its brittleness will increase in proportion to the length of time that it is thus exposed.^u Does it not therefore seem probable that in many cases at least the defects of *cold-short* iron are occasioned by an absorption of oxygen? This however the advocates for the universality of Bergman's theory on this subject may allow with perfect consistency. They would say that the phosphat of iron

^u Musset in Phil. Mag. ii. p. 161.

originally contained in the ore is converted by the process of smelting into phosphuret of iron, which being capable of uniting perfectly with bar iron and forming only a very small proportion of the whole, may render the iron hard without materially impairing its toughness while cold: but when this iron deprived of carbon is exposed at a high temperature to the action of the air, the phosphorus becomes acidified, and the phosphat of iron that hence results being incapable of combining with malleable iron is merely dispersed through it, and must therefore tend to render it brittle. Nor is the explanation of the fact contradicted by the methods made use of to correct this quality. Rinman says that cast iron which by the common treatment would yield cold short bar, may be made to afford soft malleable iron by fusing it with a mixture of equal parts of lime and scoriae. Mr. Mushet^v says that 875 grains of cold short iron when melted by itself in a covered crucible formed a perfect button covered by a thin film of brown glass. The metal weighed only 805 grains, and instead of being cold-short, was now found to have acquired the opposite fault of being hot-short, it was extremely soft and ductile. In these experiments it may be said that the metal being brought to a state of quiet fusion, the phosphat of iron either entirely or at least for the most part separated in the form of glass from the reguline portion. But as all the above phenomena may be accounted for equally well upon the supposition that the cold-short quality is owing simply to the mixture of oxyd of iron with the metal, it would be useless to speculate further on the subject till a sufficient number of accurate analyses have been performed to direct our investigations. The hot-short quality appears to be occasioned by the admixture of some substance which enters into fusion at a low red heat, and thus destroys the tenacity of the iron through which it is diffused: hence this variety of iron cannot bear the hammer at a red heat, though when the temperature is raised to the full welding point, the effect of this unknown substance is counteracted by the tenacity which the particles of iron then acquire. This substance has been by some supposed to be carbon, but this is inconsistent with the extreme softness which always characterises hot-short iron: for the same reason it cannot be phosphorus. The effects are more like those of a metallic body; and lead, arsenic, copper, and zinc may be each suspected with almost equal probability. In some varieties of hot-short iron,

especially those made with coak, the fragility increases with the increase of temperature, and they are wholly incapable of welding: this probably arises from a large admixture of the same substance, whatever it be, to which the more usual characters of hot-short iron are owing, with perhaps a little sulphur.

§ 6. *Physical properties of Iron and Steel.*

Iron whether in the states of cast or bar iron, or steel, is attractable by the magnet, and capable of acquiring polarity, this last property however is more durable and powerful in steel than in any of the other forms of this metal.

Supercarbonized cast iron is of a dark-grey almost black colour, has a granular fracture, is very brittle, is more fusible than the other kinds of cast iron, and yields without difficulty to the file. White cast iron is of a tin-white colour, and a coarse grained fracture; it is brittle but very hard, and less fusible than the preceding variety. The grey and the mottled varieties approach nearer to the one or the other in proportion to their colour. The specific gravity of cast iron has not been ascertained with great exactness, and no doubt is subject to some variations: that which is most highly carbonized has the least specific gravity, nor does it probably ever much exceed 7.01. Cast iron takes impressions from moulds with much more sharpness and precision than any other metal: and when in fusion if pieces of cast iron are thrown in, they will be observed to float on the surface till they melt and mix indistinguishably with the rest; hence it has been generally acquiesced in that melted cast iron is of greater specific gravity than when solid; contrary to what takes place in all the other metals. This however seems to be founded on a mere fallacy, for if it were true, the iron when poured into a mould and beginning to solidify, ought to spirt out part of the melted metal, as water does under similar circumstances when converting into ice: whereas on the contrary, a considerable contraction happens which obliges the workmen who are employed in casting large pieces, to fill the runners or channels into the mould with melted metal, lest any cavities should be formed in the piece and thus spoil it. Further, this contraction is so well known, that when castings of particular dimensions are required, the mould is constantly made larger than the pattern by $\frac{1}{8}$ or sometimes $\frac{1}{4}$, to allow for the shrinking. Now it is impossible that this should happen if the specific gravity of the melted metal really exceeded that of the solid metal; how then does

it happen that the solid will float on the fluid metal? the answer to this is not perhaps very obvious; but it may be remarked that not only solid cast iron but even bar iron which is of considerably greater specific gravity, and not only bar iron but even lead which is more than half as heavy again as cast iron, will float upon its surface. But though cast iron like all other metals shrinks when it becomes solid, yet at the instant of congealing it appears to undergo a momentary expansion, and thus takes a remarkably perfect impression of any pattern with which it comes in contact.

Bar iron is of a blueish white colour, has a fibrous hackly fracture, is malleable both when hot and cold, and is capable of uniting with another piece of bar iron by welding: it may be drawn into very fine wire, and is the most tenacious of all metals, a wire $\frac{1}{16}$ of an inch in diameter being capable of sustaining from 450 to 500 lbs. before it breaks. It is fusible, but requires for this purpose a higher heat than cast iron. Its specific gravity is subject to some variations: that of common hammered iron, according to Dr. Pearson, is from 7.45 to 7.6: Swedish bar iron varies between 7.70 and 7.78. It expands like all other metals by heat: the amount of its expansion for every degree of Fahrenheit's thermometer between the freezing and boiling point of water, is equal to 0.000006358.

Steel is of a light-grey colour and a fracture more or less fine granular: it is harder and more brittle than bar iron in proportion to the quantity of carbon that it contains; when slightly charged with this substance it is malleable, ductile, weldable and elastic, but when more nearly saturated with carbon it is not capable of being welded, and its fusibility is increased. It may be hardened by sudden cooling, and may afterwards be made softer by tempering. Its specific gravity varies much: that of the best blistered steel before hammering is =7.31, of the same after hammering =7.73: of very hard steel =7.26; of melted steel wire =7.5; of English cast steel hammered, from 7.82 to 7.91.

§ 7. *Chemical properties of Iron.*

Iron when heated very intensely, that is, to about 155° to 160° of Wedgewood, melts, and if in contact with air, or only loosely covered with the burning coals, it takes fire and burns with uncommon beauty and brilliance, sending forth most dazzling bluish white sparks to a considerable distance, like fire-works. This is easily shewn by heating a piece of thick soft iron wire in the hottest part of a good blast

furnace, and may constantly be observed in a blacksmith's forge at the instant that the horse-shoe or any other piece of thin iron is withdrawn to be removed to the anvil. Thin iron consumes very rapidly in this way, and falls down in a half-fused metallic slag.

The combustion of iron takes place very rapidly in oxygen gas, forming some beautiful experiments as first noticed by Dr. Ingenhouz. For this purpose fill a flask with oxygen gas, and having previously fitted a cork to it, thrust a piece of thick iron wire through, just long enough to hang down to the middle of the flask, and round this thick wire make a spiral coil of thinner wire about the diameter of packthread. Fasten to the lower end of the spiral a very small piece of lint, (previously soaked in nitre and dried), which set fire to, and immediately introduce the whole into the flask, thrusting it down as low as the cork will permit it. The flame of the lint soon communicates to the wire which kindles, and burns with great beauty, and a hissing noise, sending off bright sparks, and in proportion as the flame travels up the spiral coil, drops of melted and oxydated iron fall down, while hot, and penetrate the substance of the glass, unless some water is left at the bottom.

This experiment is performed with rather more effect in jars open at top and bottom, the top opening being much smaller and fitted with a perforated cork. The melted drops then do not crack the glass vessel as in the former case.

Another method of burning iron in oxygen, first adopted by Dr. Priestley, is by throwing the heat of a powerful lens on iron confined in a glass jar of this gas. *Cast* iron was found to burn much more vehemently than hammered iron, for the former as soon as any portion was melted gathered into a round ball, dispersing into a thousand directions like a most beautiful fire-work, and attended with a hissing noise.

Iron is also readily burnt by a powerful galvanic pile, and with the same beautiful appearance.

The result of this combustion, however performed, is a black, brittle, shining, magnetic oxyd.

There are also many other ways of oxydating iron, as this metal has a very great tendency to absorb oxygen and carbonic acid either from the air or from any surrounding substance capable of supplying oxygen, particularly water in any form.

Hammered iron if kept at a low red-heat very soon becomes rough at the surface, and

peels off into thin scales (as every one must daily observe in the iron work about common fires and pokers) which also are the metal oxydated to a low degree, and therefore still magnetic.

The common rust which collects upon hammered iron by exposure to air and moisture, and which in time corrodes the thickest bars, is not the simple oxyd, but a *carbonated* oxyd, or a compound of iron, oxygen, carbonic acid, and water, and is not of itself magnetic unless mixed with fragments of the iron detached by the rusting.

Water affords another means of oxidating iron, and several curious circumstances attend this change. When the steam of water is pressed over iron kept red hot, the water is decomposed very rapidly, its oxygen passing to the iron, and its hydrogen appearing alone in the form of *Hydrogen Gas*, (as mentioned under that article). The same change however will take place even at the common temperature of the air, but the oxyd will then be in the form of a black powder, and will not exhibit that glossy appearance which it does in the former method. The preparation called *martial ethiops* is iron oxidated by water, and was first made by Lemery the younger, in the following way: take any quantity of clean iron filings, put them in any vessel and cover them with water to about three or four fingers breadth, let them remain for a considerable time (and speedier if kept in a warm place) frequently stirring them up and supplying the waste with fresh water, so as to keep the iron covered. After a while bubbles of hydrogen constantly rise from the mass, and the vessel becomes full of a very fine black powder which may be separated from the remainder of the filings by being ground up with water and poured off before it has subsided. Let it then settle, dry it slowly, and keep it in a well-closed bottle.

This black powder is iron in the first or lowest state of oxydation, or *sub-oxyd*; it is strongly magnetic, but has a constant tendency to absorb an additional quantity of oxygen from the air or any other substance, by which it loses its magnetic property, changes from black to yellow or red, and acquires very different chemical characters. From the experiments of Proust and other chemists, it appears that these two states of oxydation of iron are very constant and uniform, that is to say, that iron has properly only two distinct modes of combination with

oxygen, namely as the *black magnetic sub-oxyd*, which is composed of about 27 of oxygen and 73 of iron; and the *perfect oxyd* the colour of which is more or less of a red, and is composed of about 48 of oxygen and 52 of iron. It seems probable that there is no proper intermediate degree of oxydation except what may be produced by mere *mechanical* mixture of various proportions of these two oxyds; but as soon as any portion of the sub-oxyd is in a state to absorb oxygen at all, it amounts to the proportion of 48 in 100 before a second portion begins to change: and vice versa when the perfect oxyd is reduced to the sub-oxyd.

The preparation of the black ethiops in Lemery's method is tedious, and many attempts have been made to shorten it. The difficulty is to arrest the oxygenation of the iron at the point in which it remains as a sub-oxyd, for the tendency which it has to full oxygenation is very strong. This is much assisted by heat, and it is found that the ethiops when exposed to air in any considerable quantity, heats spontaneously, and rapidly saturates itself with oxygen. On this subject Van Mons^a relates the following curious experiment: having collected a quantity of the black sub-oxyd, he put it while wet into a retort and heated it there to drive off the superfluous water, and at the same time to guard against the free admission of external air. When taken out the oxyd was of a very fine black, but as soon as exposed to the open air, a spontaneous motion or heaving took place through the mass, it became so hot as to burn a thick double paper in contact with it, and the whole in a few minutes was converted into the red or perfect oxyd, or *Saffron of Mars*.

Hence the sub-oxyd should be dried only in small quantities and very gradually.

Roover's process,^b which is a slight alteration and improvement of Lemery's, is to take iron filings, not fresh, but half rusted by exposure to air, moisten them thoroughly with water and let them remain twenty-four hours. This produces much black oxyd, which should be separated by grinding and decantation as usual, and a fresh affusion of water will then produce another quantity of black oxyd, which may be repeated as long as required. The oxyd is then boiled for a minute with water in an iron vessel, and afterwards dried with precaution. It is then very pure and good. The oxydation of the metal is much assisted if the water employed be slightly acidulated with muriatic acid.

^a Journ. de Pharmacie, p. 151.

The fulphat or muriat of iron precipitated by ammonia also affords a sub-oxyd generally magnetic, which will be further mentioned.

Another method of preparing this ethiops is by difoxygenating the perfect oxyd. For this purpose put any quantity in a crucible, make it fully red hot, project on it a little linseed oil or white wax, cover the crucible, and continue the heat till the contents have ceased to smoke. The carbonaceous matter here takes away all the excess of oxygen, and what remains is the black magnetic sub-oxyd or ethiops.

Another ingenious method proposed by Vauquelin of obtaining the black ethiops is by heating strongly for two hours, given proportions of the red oxyd and iron filings. The oxygen then becomes nearly equally divided throughout the whole mass, so that the red oxyd becomes changed to the black by losing oxygen which the iron filings gain in their conversion to the same.

To convert the whole into an ethiops similar to that prepared in any other way, (that is of which 100 parts contain 27 of oxygen) it will be necessary therefore to take $1\frac{1}{8}$ part of the red oxyd at 48 per cent. of oxygen, and 1 part of iron filings, that is to say, supposing no loss of oxygen, but that the whole becomes equally distributed in the mass. After all however it is still doubtful whether a perfect chemical mixture of the two ingredients can be obtained in this way.

The red perfect oxyd above mentioned is also called *Saffron of Mars*, or *Crocus Martis*, and is used both medicinally and as a polishing powder. It is the state in which iron is contained in many of its acid solutions, particularly the nitric, as will be presently mentioned. It is also produced by the calcination of the black ethiops with a red-heat in an open vessel and with frequent stirring.

None of the oxyds of iron are soluble in pure water. The oxyd scarcely melts by itself in the strongest heat, but is a powerful flux for all earthy mixtures. It parts with a portion of its oxygen by a very intense heat, and at a low red heat when in contact with carbonaceous matter. It gives to earthy and vitrescent mixtures various shades of red, yellow, and green, according to circumstances. (See the article *Glaßs.*)

Iron in the metallic state is soluble in water impregnated with carbonic acid. This carbonat is the form in which iron is found in by far the

greater number of mineral chalybeate waters. Thus an artificial chalybeate water imitating that of Tunbridge (for example) may be made simply by putting a few iron filings in a bottle filled with carbonated water, and letting it remain some hours with frequent shaking. This fact was first observed by Mr. Lane.^a If this solution be exposed to the air, it quickly exhibits on the surface an iridescent film consisting of the oxyd of iron beginning to separate. By rest the whole of the iron is deposited as a yellowish-red oxyd, which according to Bergman^b amounts to about $\frac{1}{10000}$ of the weight of the water, that is, when the latter originally contains about its own bulk of carbonic acid. This oxyd is at first magnetic, but soon loses this property, owing to a further absorption of oxygen. The pure alkalies separate this oxyd from the water but not the carbonated alkalies, hence in many mineral waters, carbonated soda and carbonated iron are found together. It is owing to the spontaneous separation of the oxyd by exposure to air that the channels and reservoirs in which the natural chalybeate waters flow are always lined with a red ochre.

The oxyds of iron are not soluble in carbonated water, when as Bergman has observed, the carbonic acid has been procured from the calcination of lime or magnesia, that is to say, when it is pure; but when from effervescing substances by means of the stronger acids, some of the oxyd will be dissolved—a convincing proof that some portion, though extremely minute, of the displacing acid is carried up with the carbonic acid gas, though too small to be detected by common tests.

Carbonated iron is readily and totally separated from the water by a boiling heat for a few minutes, which affords an easy method in chemical analysis. When carbonat of lime is also contained, most of it separates along with the iron. Heating the water will also discover whether the iron it contains is held dissolved by the carbonic or by a fixed acid; if by the former, the water will not strike a purple with galls, if by the latter, this change takes place as easily as before.

A singular circumstance has been remarked with regard to some of the hot chalybeate waters, such as those of Bath or Carlsbad, which is, that though when quite fresh and hot from the spring, they give a very decided chalybeate taste, and a slight but unquestionable purpling with galls, and blue with prussiat of potash;

^a Phil. Transf.

^b Essays on the Aerial acid.

both the taste and the power of these tests are lost as soon as the water cools, before any perceptible deposition of oxyd takes place, and even if the water be inclosed while hot in a well corked bottle, which it quite fills, and therefore without any obvious loss of carbonic acid. In these cases however there is always a slight ochery deposit on the sides of the bottle which cannot be restored by heating again, though with the vessel still closed. It is not easy to explain this circumstance, nor is it quite decided whether in these cases, the solvent of the iron is really the carbonic acid. It may be added that when the quantity of iron is extremely minute the most certain way of applying the gall nut test is to suspend with a string a small piece of the nut in the bottle, and then to fill it with the water at the spring head, and let it remain well corked for some time.

The sulphuric acid dissolves iron, and forms the well known salt *Sulphat of iron*, *Green vitriol*, *Green copperas*, or *Sal martis*. The greater quantity of this salt which is used in manufactures of various kinds, particularly in dyeing black, is not prepared from the direct combination of its ingredients, but from various kinds of native sulphats of iron or pyrites (described in § 1 of this article) after they have undergone spontaneous oxygenation by long exposure to air. Green vitriol is prepared in many counties in England; the first manufacture of the kind was undertaken in the reign of queen Elizabeth, at Deptford, where it is still carried on.^c It is likewise made largely in Northumberland and Durham. The method of manufacture is simple, and scarcely differs now from what it was more than a century ago as described by Colwall.^d

The following is the process actually in use.^e

“The usual mode of manufacturing copperas on the rivers Tyre and Wear, is by exposing iron pyrites (there called *brasses*) which are found in the collieries, to the influence of the atmosphere. For this purpose a situation is chosen inclining towards the river, of a natural strong clay. After the soil is taken off, gutters are cut in different directions, and wells of about 5 or 6 feet deep, and 2 or 3 in diameter, are sunk where the gutters terminate. Upon this surface the *brasses* are laid to the thickness of 4 or 5 feet. The vitriolization shews itself in a white efflorescence, which is washed off by the rain into the gutters and conveyed by pipes from the wells to a reservoir, from which there is a

“pipe of communication to the boiler. This is a leaden vessel generally about 7 feet deep, 12 to fourteen long, and 6 or 7 wide, where the liquor is evaporated for 6 days, during which time a quantity of old iron is added to it, as much as it will dissolve. It is then run into a crystallizing vessel, and remains there for five weeks, at the end of which time the mother liquor is run into a reservoir, and pumped back into the boiler, and the crystals are removed, and after being well drained are packed in hogsheds for sale. A single boiling from a boiler of the above dimensions yields from 5 to 8 tons of copperas, according to the strength of the liquor.”

Vitriol is made near Haguenau on the Rhine nearly in the same manner, according to the description given by Cavillier.^f The pyrites is disposed on an inclined soil in beds about two feet thick, beneath which are gutters going to a common reservoir. The vitriolization of pyrites is always seen by whitish efflorescences tasting strongly of vitriol, at the same time that the surface of the pyrites cracks in every direction. When the season is dry it is occasionally watered to carry off the vitriol already formed, and to promote a fresh vitriolization in the remaining ore. The heaps are found to be exhausted when these saline efflorescences are but scanty, and when the lump when broken appears changed throughout into the *liver pyrites*.

The vitriolic liquor is evaporated as usual in lead boilers, but it does not appear that old iron is regularly added to saturate the liquor as in England, but only occasionally when it appears too acid. Some of the mother liquor of the former operation is always added.

The evaporated liquor before it passes into the crystallizing pools is sent to another basin, where it remains for twenty-four hours to deposit a large quantity of ochre. The crystallizing pools are made of fir planks surrounded with beaten clay. It requires ten days for the solution to deposit all its crystals, part of which is collected on sticks put into the vessel, but the purest vitriol is deposited the last. The liquor that remains after the deposition of the crystals (or the *mother-water* as such liquors are always termed) is reserved, and a portion is always added to the boiler in the next evaporation.

The vitriolization of the common pyrites used in these manufactures is a work of considerable time, more or less according to cir-

^c Watson's Essays.

^d Phil. Trans. vol. xii.

^e Original communication.

^f Journ. des Mines, No. 36.

circumstances, but it is generally several months before a bed is entirely exhausted. Vitriol is however also made in several places from *vitriolic peat*, and in this the process is much shorter. A large manufactory of vitriol from this source is carried on near Beauvais in France,^s thus described by M. Briffon.

The peat in the neighbourhood is of two kinds, the common combustible peat and the vitriolic. The former is, as in other countries, light, spongy, and full of visible remains of leaves, stalks, and vegetable fibres. The vitriolic on the other hand is easily distinguished by being heavier, harder, and crumbly. The waters that run from it also deposit much ochre which readily detects the situation. The vitriolic peat is not found uniformly in any relative situation with the other species, but at different depths from the surface to about ten feet.

This peat is hardly exposed to the air before it opens of itself and becomes very dry and harsh, and soon heats even in small masses. To render the vitriolization more uniform and prevent the too drying effect of the sun, the peat is laid in heaps only three or four inches in thickness under sheds thatched with straw, where they remain for a few days, after which they are ready for lixiviation. This is done by throwing the peat into large vats of masonry and covering it with rain water, which flows through the heaps and is collected for the purpose, and also with some of the mother water of the former crystallization. It is then evaporated and crystallized in the method already described.

In some places the pyrites requires roasting before it can be decomposed by the action of the air. Thus at Geyer in Saxony^h the pyrites, after being exposed for some time to the air, is soaked in water for twelve hours, then roasted as in the ordinary method of roasting ores, in a large bed upon faggots, on which about seventy or eighty quintals at a time are heated red-hot, and in this state plunged again into water. This is repeated six times successively with the same pyrites, by which the water becomes strongly impregnated with vitriol and is afterwards evaporated and crystallized as usual.

A quantity of heat is always generated during the process of vitriolization, both in the first combination of iron with sulphur and the subsequent oxygenation of the sulphur, and consequent conversion into sulphuric acid, which

enables it to dissolve the iron and form the sulphat required.

The degree of the heat produced, and the quantity of moisture which the pyrites receives (by rain or other sources) are the circumstances that principally regulate the production of vitriol, both as to quantity and time of its production. Too much heat actually kindles the mass; the remaining sulphur takes fire, and an immense quantity of sulphureous acid vapour is given off to a great distance around. Where this takes place little or no vitriol is produced, for most of the sulphur and acid already formed is dissipated, and also the iron becomes too much oxydated to yield the crystallizable salt. Hence it is dangerous and prejudicial to make too large heaps of pyrites or to put it up into stacks however preserved from the weather. Some moisture is also necessary to vitriolization, but too much of it keeps the pyrites too cold and the process is languid. The iron added during the boiling is certainly useful, both as saturating the acid and encreasing thereby the yield of the salt, and also as precipitating by its superior affinity any copper which may arise from the admixture of copper pyrites, and also undergo vitriolization. In some manufactures however the admixture of a small portion of sulphat of copper is even an advantage, as in the dyeing of hats.

Since the method of preparing the sulphuric acid from sulphur and nitre has been universally adopted, a part of the use of vitriol of iron (namely for the production of sulphuric acid) has passed away, but it is still employed largely in the preparation of nitric acid in many places besides its extensive use in dyeing.

Sulphat of iron is also made even in the large way in London, by the direct combination of iron and sulphuric acid, which is found to answer on the whole in point of cheapness, as a purer salt is obtained, and at an incomparably shorter time. Most of the salt of this kind used in medicine is prepared in this way.

Iron is not soluble in the *concentrated* sulphuric acid when cold, but if heat is applied the acid is partially decomposed, sulphureous acid gas is given out, and the oxygen of the decomposed acid passes to the metal, and sulphat of iron is formed with the remaining acid. But when the acid is diluted the solution goes on rapidly even in the cold, much hydrogen gas is given out by the decomposed water, and sulphat of iron is formed in abundance. Some

^s Journ. de Phys. tom. 4.

^h Jars Voyages Metal. tom. 3.

heat is generated in the process. The process often becomes languid or altogether stops when the quantity of water is comparatively small, owing to the salt crystallizing round the iron and encrusting it so as to prevent the acid from reaching it. A little heat is then useful to redissolve the salt and saturate the acid thoroughly.

All the common sulphat of iron, especially that prepared in the great way from pyrites is a mixture of two distinct salts, the nature of which was first fully shewn by Proust, and which it is necessary to be aware of to understand the chemical changes that take place with this salt in different circumstances. The first of these is the *green sulphat of iron*, or that salt which gives the common sulphat its leading external characters, and of which it forms by far the largest portion when fresh made, before it has been exposed to the air.

The green sulphat is a very beautiful salt, when regularly crystallized forming rhomboid prisms, of a cold sea-green colour, with a strong styptic taste and sensibly acid so as to redden litmus. It is soluble in twice its weight of water at 55°, but in less than its own weight of boiling water.ⁱ It is insoluble in alcohol. It does *not* give a black colour with galls, and with the prussiated alkalies it gives a *white* and not a blue precipitate. These two important facts discovered by Proust very strikingly distinguish it from the common sulphat of iron. The pure green sulphat when decomposed by the alkalies gives a very light green precipitate, but which speedily grows yellow by contact with air. This salt is obtained by agitating the common green sulphat with sulphuretted hydrogen gas.

This salt as well as the common sulphat recently made, though of a pale clear green at first, soon becomes covered with a yellow ochre when exposed to the air. When the solution in water is also kept in half-closed bottles it soon grows turbid, deposits a reddish-yellow oxyd of iron, which gradually increases in quantity, and at last the whole or nearly the whole remaining liquor is changed into a red fluid, much more astringent in its taste than before, and if evaporated contains hardly any crystallizable salt, but leaves a red deliquescent mass intensely styptic. This saline substance is the *red sulphat of iron* which differs from the green sulphat in many essential characters, being uncrystallizable by common

means, soluble in alcohol, giving an immediate black with galls in any form, and a deep blue with the prussiates.

It appears from the experiments of Proust and others that these two salts differ from each other chiefly in the proportion of oxygen united to the iron in solution, the oxyd of iron of the green sulphat being composed of about 27 per cent. of oxygen and 73 of iron, and the oxyd of the red sulphat containing the metal at its highest state of oxygenation, that is at 48 of oxygen to 52 of iron, as already mentioned in describing the oxyds.

The green sulphat having a constant tendency to absorb oxygen, and thus to be converted into the red sulphat, most of the changes which each salt undergoes may be explained from this circumstance.

Scheele was aware that the precipitation of the red oxyd from the common green sulphat depended on the action of the atmospheric air, for he gives it as a test to discover this air contained in water, to put a small crystal of the purest green vitriol in a phial perfectly full of the water, to be examined, and to cork it closely; when as he observes, it will be found that in a day's time a quantity of ochre sediment will fall to the bottom, which will not take place if a similar experiment be made with distilled water recently boiled to purge it of all its air. The change from the green to the red sulphat also takes place more speedily by the addition of the nitric or oxymuriatic acid to the former salt, these furnishing the requisite quantity of oxygen. On the other hand the red is converted to the green sulphat by *difoxigenating* processes, that is, either by the contact of sulphuretted hydrogen in any form, or by adding some metallic tin, zinc or mercury, according to Proust, all of which produce this partial difoxigenation. When the red sulphat is boiled on metallic iron, as happens when the mother-water in vitriol-making is returned to the boiler, some oxyd of iron is precipitated, and part of the remaining liquor is changed to the green sulphat and crystallizes on cooling. Hence the economy of using up the mother-liquor with fresh iron, as above-mentioned. Possibly sulphuretted hydrogen might be used in vitriol-making with advantage.

The red sulphat is precipitated by the pure alkalies of a deep red colour, differing much in this from the other salt, which gives a light pea-green precipitated with the same. Ammo-

ⁱ Beaumé.

nia partially reduces the perfect oxyd if dried in a close vessel, and brings it to the black or magnetic state.

Some interesting experiments have been made by Mr. Davy* on the absorption of nitrous gas by green sulphat of iron, a combination which is found to be very valuable in EUDIOMETRY. The fact of the absorption was first noticed by Dr. Priestley. A pure red sulphat of iron was made by passing oxymuriatic gas through a solution of common green vitriol, till it gave only a red precipitate with potash. Nitrous gas being thrown up to a quantity of this solution, the colour changed to a muddy green, but the absorption was very trifling.

On the other hand a pure green sulphat was formed by dissolving iron filings in dilute sulphuric acid, agitating the solution in contact with sulphuretted hydrogen, and then boiling it. This gave a white precipitate only with prussiat of potash, and therefore was unmixed with any of the red sulphat. Nitrous gas being agitated with this solution, it soon became of an olive-brown, and a quantity of the gas equal to four times the bulk of the solution was absorbed. As long as the solution remains cold the nitrous gas does not seem to undergo any alteration; but when heat is applied a part of it is given out unchanged, but a part disappears, and at the same time a quantity of red oxyd of iron is precipitated, and some ammonia is found in the solution. No nitric acid is formed in the process, and hence the author of the experiments infers that the nitrous gas is decomposed, its oxygen passing to the iron, and producing the red oxyd, and its azot entering into the composition of the ammonia; and to account for the hydrogen, the other constituent of the ammonia, recourse is had to the supposition of a concomitant decomposition of water, whose oxygen also assists in the full oxygenation of the iron.

The green sulphat of iron, according to Kirwan contains in 100 parts, 28 of black or sub-oxyd of iron (at 27 in 100 of oxygenation) 26 of real sulphuric acid, and 46 of water, of which he estimates 38 to be water of crystallization and the remaining 8 to be water of composition.

Green vitriol when heated melts in its own water of crystallization. When all this is driven off by a boiling heat, there remains a grey mass commonly called calcined vitriol. The salt has lost only water by this first pro-

cess, as is proved by performing it in a retort and collecting the liquor driven off by the heat. It was formerly called *dew of vitriol*, and several fanciful alchemical properties were ascribed to it. If the calcined vitriol be urged in a strong heat, and confined in a porcelain or luted glass retort, sulphureous acid gas mixed with sulphuric acid comes over and continues to do so for a considerable time, till the salt has been for some time fully red-hot. What remains is a blood-red mass, consisting of a perfect oxyd of iron with a small portion of still undecomposed sulphat of iron, which being now in the state of the red sulphat is deliquescent, and causes the mass to grow damp by exposure to air. This red mass is called *colcothar*, and is much used for polishing metals, glass, &c. but is previously washed in warm water to extract every thing saline that remains. If colcothar is further urged with a very intense white heat, a large quantity of oxygen gas is given out, and an oxyd of iron is left, which is slightly magnetic, and therefore in the state of a sub-oxyd. Therefore the decomposition of the sulphuric acid first affords a quantity of oxygen to unite with the iron naturally in the state of sub-oxyd in the salt, and a very intense heat again drives off this additional oxygen, and leaves the iron nearly as at first. Along with the sulphureous gas that is given out so abundantly in distilling green vitriol, a quantity of a very strong smoking and peculiar sulphuric acid comes over, which concretes in the receiver in long striated rays or crystals. This acid from the place of its first production was called *smoking vitriolic acid of Nordhausen*. It is now found to be sulphuric acid saturated with sulphureous acid gas, to which it owes its concrescibility. (See SULPHURIC Acid.)

The red sulphat of iron is generally considered as uncrystallizable, and to differ strikingly in this respect from the green sulphat, but Mr. Hauffman† gives several examples of crystals being formed in this solution which appear to be this sulphat of iron in the highest state of oxygenation. This accurate chemist relates that on mixing together a pound of nitrat of iron and half a pound of concentrated sulphuric acid, and evaporating the whole to dryness in a porcelain dish, a white insipid residuum remained, which on being left to itself for some weeks had deliquesced and acquired an astringent taste. The deliquesced liquid being then poured off and kept in a glass, gradually deposited beautiful colourless transparent

* Recherches.

crystals resembling alum, which immediately gave a blue precipitate when added to prussiat of potash. These crystals had an intensely astringent taste, became yellowish in the air, and when dissolved in water and heated deposited a yellow oxyd.

The same chemist also obtained crystals of this sulphated oxyd of iron by dissolving the perfect oxyd procured from the nitrated iron by potash in sulphuric acid, and adding an excess of the acid.

Also, when common sulphat of iron saturated with nitrous gas or mixed with nitric acid is simply evaporated to the consistence of honey, no crystals are formed, but on adding about a sixth of sulphuric acid, the whole becomes a confused crystalline mass.

These experiments would seem to shew that this sulphated oxyd of iron requires a greater excess of acid to crystallize than the sulphated sub-oxyd or green sulphat, but this opinion does not correspond with the fact that in the gradual conversion of the green to the red sulphat by exposure to air and heat, a large quantity of insoluble oxyd is precipitated, so that the common solution of uncrystallizable red sulphat that is left must contain even more acid proportionally to the iron than the crystallized green sulphat.

Further experiments on this subject are still wanting.

The action of the sulphureous acid upon iron has been investigated by Berthollet, and afterwards by Fourcroy^a and Vauquelin. When liquid sulphureous acid is poured upon iron filings it immediately becomes of a deep buff colour, some hydrogen gas is given out, much heat is excited, and the colour soon changes to green. With other acids the solution then gives out sulphureous acid gas, and at the same time lets fall a white powder which is true sulphur. A large quantity of the acids is required for this. The nitrous acid separates the sulphur as a ductile mass.

The solution of iron in the sulphureous acid, or the *sulphite* of iron, deposits a reddish-yellow crystalline powder, of which when washed in water the saline part dissolves, and a residue is left which is sulphur holding a little iron. This saline part is a simple sulphite of iron, or one in which there is no excess of sulphur, and when exposed to the air it gradually passes to the state of sulphat as takes place with the alkaline sulphites. The sulphite of iron does not give a black with galls nor a blue with the prussiated

alkalies, and hence it is probable that the iron is in its lowest state of oxygenation.

Nitric acid dissolves iron with extreme vehemence when a little diluted with water, for when quite concentrated it does not act on iron any more than on tin. The action of this acid on iron is attended with copious red fumes, consisting chiefly of nitrous gas and nitrous oxyd. At the same time much yellowish-red oxyd of iron separates, so that the solution is sensibly acid. When much concentrated it often suddenly takes a gelatinous form. The solution at first is of a light green, but when nearly saturated assumes a deep-red colour. When the action of the acid is very powerful, ammonia is formed, as is shewn by adding lime to the solution, which immediately gives an ammoniacal smell. This nitrat of iron is not crystallizable, when evaporated to dryness it leaves only a red viscid mass very deliquescent. It gives a strong blue with the prussiate and a black with galls, and appears to contain the iron therefore in its highest state of oxygenation. It has little if any power of absorbing nitrous gas.

There is another state of nitrat of iron which may be called *nitrated sub-oxyd of iron*, and is procured by digesting slowly and without heat a very dilute nitric acid upon iron, not in very small divisions, or else by adding lumps of iron to the common solution. In the latter case much of the perfect oxyd falls down, and the metallic iron appears to take its place. This solution of iron in very weak acid gives out, while forming, but very little gas for some time,^b and becomes dark-olive brown. When neutralized by the alkalies it gives a light green precipitate. With galls however it gives a black, and with the prussiate a green precipitate, so that it appears to be a mixture of the two species of nitrats. In this state it will absorb much nitrous gas. When heated it passes to the state of the first-mentioned nitrat.

Nitric acid will not dissolve iron much oxygenated, and therefore in chemical analysis boiling to dryness a small quantity of nitric acid off any oxyd of iron is often used to bring it to an uniform state of oxygenation (in this case the highest) by which its proportion of metal may be fairly estimated. A hundred parts of this oxyd therefore, when fully dried, are equivalent to 52 of metal and 48 of oxygen, as already repeatedly mentioned.

When the nitrat of iron is decomposed by carbonated potash an excess of the alkali re-dis-

^a Systeme de Con. Chem.

^b Davy, Researches.

olves the precipitate, as will be presently noticed.

The oxymuriatic acid oxydates and dissolves iron. The oxyds of iron are dissolved by it with difficulty, but if a quantity of the carbonated oxyd or rust be diffused in water, and oxymuriatic acid gas passed through it, or, more simply, if the rust a little wetted be put on a flat dish, and exposed to the vapour of this acid, a solution is effected, and a brown liquor of a very styptic taste is produced, but which has not been much examined.

Muriatic acid dissolves iron and its oxyd with great ease, more so than any other acid, and several interesting combinations are produced thereby.

When this acid is poured on iron filings a great quantity of hydrogen gas of a very peculiarly foetid smell is given out, and a solution is effected, which is of a pale-green if kept excluded from air. This is generally turbid at first with a number of black specks, which are the carburet of iron that this metal almost always contains, and is insoluble in the acid. This solution gives a white precipitate with prussiated alkali, and a light-green oxyd with the pure alkalies. It has a strongly styptic acid taste. By evaporation from a vessel with a small orifice, so as to exclude the air as much as possible, it gives greenish-white crystals, insoluble in alcohol, but very soluble in water.¹

A similar variety takes place in the muriated as in the sulphated iron, that is, there are two very distinct salts, the one already mentioned being the green muriat or muriated *sub-oxyd* of iron, and which by absorption of oxygen readily changes to the red muriat, or that in which the iron is completely oxygenated.

The green muriat alters much less by simple exposure to air without heat than the green sulphat, but in time the colour of the solution reddens, and some red oxyd of iron separates. The same takes place more speedily when the solution is heated, or when a few drops of nitric or oxymuriatic acid are added. This red muriat of iron is also formed directly by adding muriatic acid to the perfect oxyd of this metal. It differs from the other both in colour and in taste, being much more astringent, and in not being crystallizable, for when evaporated nearly to dryness it only leaves a dark orange-coloured saline magma, soluble in alcohol. This solution is used in medicine. With the alkalies it gives a red precipitate, and with the prussiated alkalies a very deep blue.

The same phenomena take place with regard to the mutual conversion of the green and red muriat into each other as with the green and red sulphat, sulphuretted hydrogen changing the red to the green muriat, and oxymuriatic or nitric acid changing the green to the red. The green muriat also absorbs nitrous gas even more rapidly than the sulphat, and to double the extent, giving a very dark-brown solution. The red muriat on the other hand absorbs scarcely a particle of the gas.

If concentrated muriatic acid is heated upon red oxyd of iron a little oxymuriatic acid gas is given out.

Muriatic acid when heated, always carries off with it, as it evaporates, a small portion of iron, and to this is to be attributed the colour of common muriatic acid when made in the large way. If the saline mass, that remains when common muriat of iron is evaporated nearly to dryness, be further heated in a retort, a liquid muriat of iron sublimes, which on cooling, concretes into small yellow needled crystals on the sides of the receiver. If the remaining mass be further urged with a full red heat, a sub-muriated oxyd of iron sublimes which crystallizes in six-sided plates.¹ The crystallized muriat is soluble in alcohol, and is the basis of some empiric medicines.

The acetous acid dissolves iron and its sub-oxyd, forming a brown-red solution not crystallizable. It has not been much examined. An impure acetite is used very largely in *Dyeing* and *Calico printing*. It is made chiefly of sour beer and other substances that have undergone the acetous fermentation, and lately of the pyromucous acid arising from the distillation of charcoal for the manufacture of gunpowder.

Mr. Hauffman in his memoir on the formation of ammonia^k gives a method of preparing the acetited oxyd of iron highly oxygenized by adding to sulphat of iron dissolved in dilute nitric acid, or else saturated with nitrous gas, a solution of acetited lead, sulphat of lead falls down, and the solution contains the acetited oxyd of iron. Acetited iron may also be made more simply and elegantly by adding acetited potash to its weight of common sulphat of iron, rubbing them together, which makes a deliquescent mass, and then adding warm alcohol to the mixture. An acetited iron is made by double decomposition, which alone is dissolved in the alcohol, the sulphat of potash being left. This alcoholic solution is used sometimes in medicine, and is the *Tinctura Ferri Acetati* of

¹ Davy.

¹ Fourcroy.

^k Journ. de Phys. tom 30.

the Dublin Pharmacopœia. By gentle heat the alcohol evaporates and the acetited iron is left.

The phosphoric acid acts upon iron but slowly. The native phosphat, and its effect on the texture and manufacture of iron have been already described. The phosphat of iron is in its common state a salt insoluble in water. The observations of Fourcroy and Vauquelin on this salt are interesting. Vauquelin found it to compose the greater part of the brittle scales which rapidly form on the surface of iron, and corrode it through in no very great length of time, when exposed to be perpetually moistened with urine. These scales are much more bulky than the iron which furnishes them, are very brittle, full of knobs, and when examined closely, their fracture presents a glossy spathose semi-crystalline texture. Heated in a crucible they melted without difficulty, and gave an uniform grey metallic button of a very hard and close grain, which was phosphat of iron, and covered with a greenish porous scoria of phosphat of lime holding oxyd of iron.

Phosphat of iron is also prepared by adding a solution of phosphat of potash or of soda to the sulphat, nitrat, or muriat of iron. A white precipitate of phosphat of iron is formed by double decomposition, which like many of the other phosphats is soluble entire in many of the acids, and precipitable thence by ammonia without alteration.

In examining the nature of the colouring matter of BLOOD,¹ the same chemists discovered another species of phosphat of iron, namely with excess of base, or what amounts to the same, with a deficiency of acid, and which therefore may be termed a *sub-phosphat of iron*. If the calcined residue of blood, after all the volatile parts have been driven off by heat gradually increased to redness, be treated with weak nitric or muriatic acid, a portion is dissolved, the residue being left redder than before. The solution saturated with ammonia deposits a grey precipitate, which is the common phosphat of iron. This transferred when still wet into caustic potash partly dissolves into a deep blood red liquor. The potash here first deprives the phosphat of iron of a portion of its phosphoric acid but not the whole, and the remainder is sub-phosphat of iron, which by dissolving in the alkaline liquor gives it the deep red colour, so that the solution appears to be composed of phosphat of potash, sub-phosphat of iron, and a large excess of pure potash. They also find

that this sub-phosphat of iron dissolves readily and without heat in liquid albumen, as the white of an egg beat up with water, and also in the serum of blood, (both of which contain uncombined soda) and give them a deep red colour. An additional quantity of alkali heightens the colour.

The succinic acid forms with iron a brown saline mass insoluble in water. The affinity of this acid for iron appears to be very strong, and its insolubility perfect, and hence it has been proposed lately by M. Gehlen as a very useful and discriminating test for this metal held in solution by any other acid. The succinic acid however before it can be used in this way, should be saturated with an alkali, generally soda, and the solution to which the succinat of soda is applied should also be previously neutralized with the same alkali, but so as not to render it cloudy. The sulphat, nitrat, muriat, and other known solutions of iron are then decomposed by the affusion of the succinat of soda or ammonia, and a loose brown-red precipitate of succinat of iron falls down. Professor Klaproth in using this test^m collects the precipitate, ignites it by itself in a covered crucible, which gives some small blue flame, owing to the destruction of the succinic acid; rubs the calcined residue with a very little linseed oil, and again ignites it in a covered crucible, which reduces the iron to the black magnetic sub-oxyd.

The first calcination of the precipitate leaves the iron in the same state, so that the treatment with linseed oil is only a measure of precaution.

Dr. Marcet however has found in his analysis of the Buxton chalybeate water,ⁿ that the succinat of ammonia is not so exclusively a precipitant of iron as has been supposed, as it will equally separate alumine from its solutions, but not the other earths.

The oxalic acid readily dissolves iron with effervescence, forming a sweet astringent solution;^o when made without heat it yields prismatic crystals of a greenish yellow colour, with excess of acid and very soluble in water. When calcined there remain 45 parts from 100, which are red oxyd of iron. The oxyd of iron is soluble in this acid, but with difficulty.

Tartareous acid dissolves iron with effervescence and disengagement of hydrogen, and forms a red gelatinous mass which does not crystallize. When this acid is poured into a solution of sulphat of iron no precipitate is at

¹ Systeme de Conn. Chim. tom 9.

^o Saunders on Mineral Waters, second edition.

^m Analysis of Gadolinite. Essays, vol. 2.

ⁿ Bergman on Acid of Sugar.

first formed, but on heating the mixture, according to Retzius,^p the acid unites with the portion of oxyd which is naturally separated from the sulphat by heat, and lamellar crystals of tartrited oxyd of iron are deposited.

Cream of tartar, or the super-tartrate of potash also dissolves iron with ease, and this combination is well known in medicine. The tartarized iron is prepared by mixing together one pound of iron filings with two pounds of cream of tartar, and moistening it with a pint of water and exposing it to the air for a week, then gently evaporating the mixture to dryness. This gives a brown powder consisting of cream of tartar and oxyd of iron. But a more perfect mixture is formed by boiling together 8 ounces of cream of tartar, with 2 of iron filings in about 6 pints of water. The cream of tartar dissolves in the water with part of the iron, and on cooling, the clear liquor deposits crystals, which are therefore tartrate of potash and iron. A further evaporation yields more of these crystals. This mass remaining after the crystals have deposited, is soluble in alcohol, and forms the *Tartarized Tincture of Iron*.

Some other varieties of these preparations are employed which need not be enumerated.

It is however a property peculiar to the tartareous acid to render iron soluble in caustic alkali, or to prevent the precipitation of iron from its solution in other acids even by a large excess of alkali, which without the presence of the tartareous acid would be immediately deposited. So Klaproth in his analysis of umber,^r added to the muriat of iron, produced by digesting umber in muriatic acid, some tartrate of potash, (soluble tartar) and afterwards supersaturated the whole with caustic soda, but no turbidness was produced, but only a clear brown-red liquor. Caustic ammonia had the same effect. This red liquor was therefore a compound of oxyd of iron, tartareous acid, potash, soda, and muriatic acid, and (in this case also) oxyd of manganese.

The combination of the gallic acid with iron has been already repeatedly mentioned in this article, and also under *INK* and *GALLIC ACID*, (which see.)

The discovery is due to Proust of the circumstance that the *sub-oxyd* of iron, either as a sulphat or a muriat is not precipitated by galls, nor in any degree blackened, hence it is doubtful whether when gallic acid is added to a salt of this species any decomposition is effected, or whether a gallat of iron is really produced, but

colourless, and soluble in the remaining liquor. But the salts with the perfect oxyd are immediately decomposed by the gallic acid, and the well known black inky precipitate slowly separates. This precipitate of black gallat of iron is light and bulky so as to subside extremely slowly, and scarcely at all when the liquor is thickened by mucilage, as in common ink.

The prussic acid forms with oxyd of iron one of the most important combinations, and one which has more engaged the attention of chemists than any other of the ferruginous salts. It will be described under the article *Prussiat*, (which see). As with the gallic acid, an equal difference takes place in the combination of prussic acid with iron according to the degree of oxygenation, also discovered by Proust. With the sub-oxyd, the precipitate is white, and with the perfect oxyd, blue.

The salts produced by the combination of the *Arsenic* acid with iron have already been mentioned in this article under the method of analysing the natural arseniat of iron.

It appears probable that all the acid salts of iron are capable of these two modifications, so often mentioned, depending on the different state of oxygenation of the metal; that is, according to Proust, where the metal forms 73 per cent of the oxyd, and where it forms only 52.

The alkalies when caustic have no power of dissolving iron. The fixed alkalies precipitate it from its acid solutions apparently in the same state of oxygenation in which it existed in the solution: but as the sub-oxyd has always a strong tendency to absorb oxygen from the air, and as this action is particularly assisted by heat and moisture, it generally happens that the precipitate in the usual course of proceeding, especially when heat is used, is in the state of the perfect oxyd by the time it is thoroughlyedulcorated and dried.

But ammonia, on account of its ready decomposition by most metallic oxyds, and the disoxygenating property of the hydrogen disengaged in the process, when used as a precipitant of the salts of iron leaves the metal in the state of sub-oxyd when dried without much access of air, and will deoxidate the red oxyd when digested with it in a stopped bottle, at the same time that bubbles of azotic gas are disengaged.^s

The effect of the tartareous acid in rendering iron soluble in the alkalies has been already mentioned.

^p Fourcroy system. tom. 7.

^r Pharm. Lond.

^s Essays, vol. 2.

^t Fourcroy.

The carbonated alkalies on the other hand dissolve the oxyd of iron with ease. This solution was first noticed by Stahl, and is called after this eminent chemist the *Alkaline Tincture of Iron*. This preparation was originally made by adding to nitrat of iron the *oil of tartar per deliquium*, or common carbonat of potash deliquesced in the air. The first effect is to precipitate a red oxyd from the solution: but when the alkali becomes in excess, the oxyd is redissolved and forms a blood-red liquor. The deliquiated carbonated potash is really preferable to a solution of the salt made directly, as this alkali during exposure to air absorbs carbonic acid rapidly, and the power of dissolving the oxyd of iron depends on the proportion of carbonic acid united with the alkali. Hence the crystallized carbonat of potash is still better for this purpose. The carbonats of soda and ammonia are equally powerful in dissolving the precipitated oxyd, and not only the nitrat, but any other salt of iron will succeed.

These solutions are all decomposed by exposure to air, especially assisted by heat, owing to the escape of the carbonic acid. They are also decomposed both by the stronger acids, and by the alkalies in a caustic state, the former act by saturating the excess of carbonated alkali and driving off the carbonic acid, the latter simply by absorbing so much carbonic acid that the quantity contained in the whole solution is not sufficient to hold the oxyd of iron dissolved. The *Alkaline Tincture* decomposed by nitric acid added gradually so as not to pass the point of saturation, deposits the red oxyd of iron which made in this manner was called *Stahl's Aperitive Saffron of Mars*. An excess of the acid redissolves the precipitated oxyd.

Many of the neutral salts act powerfully on iron, forming combinations, some of which have been noticed by chemists.

If one part of clean iron filings be rubbed with two or three parts of nitre, and the mixture thrown by spoonfuls into a clear crucible made fully red-hot, the mixture burns with great brilliance, throwing out numerous bright sparks that have a very striking effect. This combination is used in some fire-works. After the deflagration is over there remains a half-fused mass consisting of the iron reduced to the state of red oxyd and diffused but not dissolved in a saline mass strongly deliquescent. This salt is the alkali of the nitre in a caustic state. If warm water is poured on the mass, the alkali readily dissolves, leaving a red oxyd of iron in a pulverulent state. This oxyd is

Zwelfer's Saffron of Mars. If the iron is more than will engage all the acid of the nitre, some of it will remain metallic, if the nitre be in excess, the lixiviated saline solution will contain some undecomposed nitre together with the caustic potash.

Iron readily decomposes muriat of ammonia when *assisted by heat*, though on the other hand ammonia precipitates the muriat of iron. When equal parts of iron filings and sal-ammoniac are intimately mixed together and heated, the decomposition is very considerable, much of the muriatic acid unites with the iron, much of the ammonia flies off in the form of gas, or, if the experiment be made with a retort and receiver, part of the volatile alkali condenses with the water of the salt in the receiver. But a portion of the sal-ammoniac escapes decomposition and sublimes at a sufficient heat in its usual form. But as muriat of iron is also partly volatile when heated, some of this latter also rises in intimate combination with the volatilized muriat of ammonia, and the salt that concretes is therefore a mixture of the muriats of ammonia and iron, but generally with the former in much greater proportion. The iron also must be oxydated before it can become soluble in the muriatic acid, and this is doubtless effected by the previous decomposition of the water of crystallization of the sal ammoniac, and hydrogen gas is actually found mixed with the ammoniacal gas during the sublimation.

This salt is much used in medicine, and is called *Martial Flowers* or *Ferrum Ammoniacale*. As the object in the preparation of it is to decompose the muriated ammonia as little as possible, only a small quantity of iron should be used, the least proportions being about 16 parts of muriated ammonia and one of iron filings. These are mixed together and put into a subliming vessel, and a heat applied gradually increased to redness. Some ammoniacal and hydrogen gases are given out, and a quantity of crystallized martial flowers is found concreted at the upper part. This salt is of a reddish yellow, and somewhat deliquescent, both which properties are owing to the presence of muriated iron. When the quantity of iron filings is increased, more ammonia is given out, and of course less of the sublimed salt is yielded, but on account of the greater proportion of muriat of iron produced, the sublimed salt is redder and more deliquescent. The proportions of iron and sal-ammoniac prescribed in the London pharmacopœia are one of the former and two of the latter. It is an inconvenience of this pre-

paration that it is not of itself uniform in the dose of iron, as the quantity of muriat of iron which rises in the sublimation, is constantly increasing. This inequality is remedied by mixing the first entire sublimate with the residue and again subliming, and afterwards mixing the whole sublimed salt uniformly by triture.

Iron when oxydated decomposes muriat of ammonia more easily than when in the reguline state, and the martial flowers are sometimes made by mixing equal weights of the red oxyd and muriated ammonia, and subliming.¹ Much ammoniacal gas escapes, but part also of the muriat of ammonia rises undecomposed, and mixed with the muriat of iron in the form of the martial flowers.

In both these processes a mass of muriat of iron remains in the bottom of the subliming vessel after the sublimation is finished.

Iron unites to sulphur with great ease and in several proportions. The sulphuret of iron is commonly made by melting together equal parts of sulphur and iron filings in a covered crucible, with a moderate red heat, which proves sufficient for perfect fusion, and the result is a metallic, shining, grey-black mass, very hard and brittle. Another and still simpler method is to make a piece of thick iron wire or any other bar iron white hot, to take it out of the fire and immediately press a roll of sulphur upon the heated parts, whereby the two will instantly combine and fall in drops of black sulphuret into water placed beneath.

When the sulphur and iron filings are heated together, as soon as they become red hot the combination takes place with sudden rapidity, and the evolution of great heat and flame, even without the access of external air. The like happens when iron filings are heated red hot in a retort or close vessel, and sulphur dropped upon them, an incandescence immediately takes place, as was remarked by the ancient chemists, and the black sulphuret is produced. The black oxyd will also combine with sulphur when heated with it in a close vessel, but with much more difficulty than metallic iron does.

Sulphur and iron filings will also chemically unite, and during their combination give out much heat. If equal parts of the two be well mixed, and moistened with water to a pasty consistence, and exposed to the air, the mass soon heats, swells, cracks in every direction, evolves sulphuretted hydrogen, and if the mass be about five or six pounds of each ingredient, the gas takes fire, as during the vitriolization of pyrites.

This actual combustion appears to have been first observed by Lemery the elder, who attributed the explosion of volcanoes to this cause, and succeeded in forming something like a volcano in miniature, by burying a large quantity of the materials a foot or two under ground. Beaumé describes the phenomena of this combination with his usual accuracy, and upon a very large quantity.²

One hundred pounds of iron filings and as much sulphur in powder were mixed, moistened, and put into an iron pot. About six hours after, a small quantity of water oozed out from the mass, which had a vitriolic taste; in five hours the mixture swelled and cracked in every direction, and began to heat, and send forth an aqueous vapour, which gradually increased during ten hours more, when the whole steamed so strongly that the pot could hardly be distinguished, and the vapour then acquired a very strong fetid smell of sulphur; after which it took fire and burnt with a flame about a foot in height for two or three minutes, and gave out a sulphureous smell, leaving the mass glowing hot, which continued to burn with frequent sparkling for forty hours longer. In this operation the principal part of the phenomena must be ascribed to the decomposition of water by the sulphuret of iron, as soon as formed, whence the production of the hydrogen holding part of the sulphur in solution: the oxygen of the water unites partly to the iron and partly to the sulphur, so that the several products are sulphuretted hydrogen, sulphuret of iron, and finally sulphat or sulphite of iron, which again, if the heat be very strong, is in its turn decomposed, as in the calcination of common green vitriol, and at last only a red oxyd of iron is left. The mixture of iron filings and sulphur appears to begin its oxygenation by absorbing this principle from the air, whence it forms a very good eudiometer, as described under that article; and by this the distinct existence of the oxygen of the atmosphere was first discovered by the illustrious Scheele; for the absorption of atmospheric oxygen from any confined portion of air by this mixture takes place before the evolution of hydrogen. If the quantity of materials be small, and the heat produced be only moderate, the residue after all mutual action has ceased, is a black sulphuret of iron, capable of yielding much sulphuretted hydrogen with acids, and mixed with some sulphat of iron that may be separated by lixiviation.

It has been a question in what state the iron

¹ Pharm. Edin.

² Chym. Exper. tom. 2.

exists in the perfect sulphuret made artificially by fusion as well as in the natural pyrites. By the valuable researches of Prof. Proust,^v corroborated by those of Mr. Hatchett,^w it appears to be satisfactorily determined, that the iron is absolutely or very nearly in the metallic state, or in other words, that the sulphuret of whatever kind is composed simply of iron and sulphur.

Another important fact also ascertained by Proust is the existence of two very distinct species of sulphurets, the one with a larger, the other with a smaller proportion of sulphur, the latter of which may therefore be termed for the present the *sub-sulphuret*, and the former the *super-sulphuret*. This distinction is confirmed, and some other valuable observations are added by Mr. Hatchett in the paper above quoted. The distinction particularly applies with accuracy to the natural sulphurets, of which the different varieties of common unmagnetic pyrites are the sulphurets with excess of sulphur; and the magnetic pyrites described by Mr. Hatchett is the natural sub-sulphuret as already mentioned when treating of the ores of iron. The artificial compounds too in some degree follow the same tendency to unite with determinate doses of sulphur, possessing respectively peculiar chemical properties, but with less accuracy than the natural, since indeterminate degrees of sulphuration of iron may be artificially procured.

Several of the experiments of the two eminent chemists here mentioned deserve particular notice. It may be premised that the great chemical difference between the two species is that the super-sulphuret (the common pyrites when natural) is not magnetical, is nearly insoluble in muriatic or sulphuric acid, and especially gives no sulphuretted hydrogen by the action of these acids; whereas the sub-sulphuret (the magnetic pyrites when native) is obedient to the magnet, and readily dissolves in these acids, with copious evolution of very pure sulphuretted hydrogen. Both the natural and artificial sub-sulphuret may be converted to the super-sulphuret by an additional dose of sulphur; and vice versa, the super-sulphuret changed to the sub-sulphuret by taking away the excess of sulphur.

Prof. Proust gives the following experiments: a mixture of iron filings and sulphur (at random quantities) was heated moderately in a retort, to procure the black sulphuret for the use of the laboratory, to obtain sulphuretted hydrogen gas.

This appearing to be not sufficiently charged with sulphur, was heated again with a fresh quantity, keeping the crucible in a red heat, but not equal to the fusion of the materials. But on treating the sulphuret thus obtained with an acid, he was surprised to find no sulphuretted hydrogen given out. Comparing this circumstance with the well known fact that common pyrites gives no gas with acids, nor is soluble in them till it is partially desulphuretted by roasting, it appeared obvious that there existed at least two distinct states of sulphuration in the artificial as well as the natural pyrites, with separate chemical properties.

Some natural pyrites which had been deprived of about 20 per cent. of sulphur by previous heating in a close retort, so as to exclude the air, and had become thereby soluble in acids and of a black colour, was then mixed with a large and indeterminate quantity of sulphur and exposed to a moderate heat in a retort by the side of another retort filled with some of the same pyrites in its natural state. The use of this last was to serve as a thermometer to regulate the heat, which was kept just below the point at which pyrites yields its excess of sulphur. The contents of the first retort first parted with a quantity of sulphur, but after this had ceased, nothing further was given out during an hour longer of heating, in all which time the natural pyrites underwent no change. The roasted pyrites was found after this to have acquired again rather more sulphur than it had lost, and had resumed its greenish yellow hue, but it still remained pulverulent. It *now* gave only a very small quantity of sulphuretted hydrogen by immersion in sulphuric acid, and remained insoluble in it though heated to boiling. Therefore, in every thing but in the crystallized form, the sulphuret had returned completely to the state of the natural pyrites, some slight differences excepted, which always must attend the laboratory attempts to imitate nature.

The sub-sulphuret and super-sulphuret were also made entirely artificially by first heating in a retort to full redness 200 grains of iron filings with sulphur till all the excess was volatilized, which left 318 grains of the black or sub-sulphuret, being an increase of 59 of sulphur in 100 of iron; and then heating this sulphuret with another dose of sulphur, (using a separate vessel of natural pyrites as a thermometer, as in the former case) which gave 378 grains, and was in the state of super-sulphuret or in chemical properties resembling the common pyrites.

^v Jour. de Phys. tom. 53 and 54.

^w Phil. Transf. for 1804.

From the above experiments therefore it appears that iron may be combined artificially with at least two very distinct doses of sulphur, or rather, that there are two distinct points of extreme sulphuration of iron, *according to the temperature used*. The first is iron united with the utmost quantity of sulphur which it will retain in a close vessel when heated fully to redness, or to that degree in which the common pyrites loses about 20 per cent of its sulphur. This gives the black sub-sulphuret, soluble in acids with evolution of sulphuretted hydrogen. The second point is when iron already sub-sulphuretted, is heated with more sulphur at a temperature just below the former, or such in which common pyrites loses none of its sulphur, and the product of this is the super-sulphuret of iron, insoluble or nearly so in acids, and giving no gas.

These two sulphurets seem to be the only ones hitherto found in nature, the super-sulphuret being the common pyrites, and the sub-sulphuret the magnetical pyrites, but in artificial combinations a great many intermediate degrees of sulphuration may be effected. Thus a lower degree than is ever found native is that in which a little sulphur is dropped upon red-hot iron filings, exciting a vivid combustion even in close vessels as already mentioned, and in which, according to Proust, 100 parts of iron acquire only from 20 to 30 of sulphur. There are besides intermediate states of sulphuration between the sub-sulphuret and the super-sulphuret as fully ascertained by the valuable experiments of Mr. Hatchett.

Professor Proust gives the following proportions of the two sulphurets, namely, in the *sub-sulphuret*, (meaning the artificial, this chemist not being then acquainted with the composition of the magnetical pyrites) 100 parts of iron absorb about 60 of sulphur, so that 100 of the sub-sulphuret contain 62.5 of iron and 37.5 of sulphur: and in the *super-sulphuret*, natural or artificial, 100 parts of iron absorb 90 of sulphur, so that 100 parts contain 52.64 of iron and 47.36 of sulphur. These proportions however appear from Mr. Hatchett's experiments to be not quite accurate.

The sub-sulphuret may also be conveniently prepared, according to Proust, by half-filling a crucible with common pyrites, covering it with a third or half its weight of iron filings, and over this a little charcoal-powder, and heating the whole red-hot for about a quarter of an hour. The heat need not be urged to fusion

of the materials. Or the pyrites and iron filings may be previously mixed. This gives a black brittle pulverulent sub-sulphuret which is the most convenient substance for the use of the laboratory for obtaining sulphuretted hydrogen gas.

Mr. Hatchett in his analysis of the natural sub-sulphuret of iron or magnetical pyrites, found it to agree in composition and all essential chemical characters with the artificial sub-sulphuret examined by Professor Proust, and to be composed of about 37 of sulphur and 64 of iron. But the composition of the natural super-sulphuret, or common pyrites, Mr. H. finds on the average of five experiments made on specimens, the most dissimilar in external appearance, to be 53.24 of sulphur and 46.76 of iron, whereas Proust estimates it at only 47.36 of sulphur and 52.64 of iron. As in Mr. Hatchett's analysis the difference between the highest and lowest quantity of sulphur in all the specimens did not amount to more than 2.19, it is probable that this disagreement depends chiefly on the mode of analysis, which being conducted in the moist way by Mr. H. we must consider as by much the most accurate. Mr. H. also obtained an intermediate sulphuret between the two species by distilling some of the magnetical pyrites with thrice its weight of sulphur in a retort, with a heat gradually raised to redness. This produced a greenish-yellow pulverulent mass, in which the sulphur was about 46 per cent. or 9 per cent. more than in the magnetical pyrites, and which gave no sulphuretted hydrogen with muriatic acid, though it partially dissolved therein.

The circumstances in which the sulphurets of iron are affected by the magnet, as shewn by Mr. Hatchett in this memoir, are very remarkable.

In all states of sulphuration the iron appears to be in the metallic state, and therefore of itself magnetic, but whilst the sub-sulphuret of 37 per cent. of sulphur is strongly magnetic, the common pyrites and the artificial super-sulphuret (of 52 per cent. of sulphur) are not in the smallest degree so, unless mixed with interspersed iron, to which alone the magnetic property is owing.

Sulphur therefore in a certain proportion deprives reguline iron of the magnetical property, and the exact point of sulphuration at which this ceases is not ascertained, but Mr. H. found this property still retained in the above-mentioned intermediate sulphuret of 46

per cent. of sulphur, and therefore it is lost somewhere between 46 and 52 per cent. of sulphuration.

The alkaline sulphurets have little if any action on iron but dissolve its oxyd, and acquire thereby an intense green colour, which the affusion of an acid immediately destroys.

Sulphuretted hydrogen added either in gas or in a liquid form to any solution of iron, first deoxygenates it entirely or partially, and then forms a black precipitate of hydro-sulphuret of iron. This precipitate is however resolvable in most acids, or may be prevented from forming by previously acidulating the solution, in which respect it differs from the hydro-sulphuret of lead; and hence in examining wines and other liquors supposed to contain lead, this metal is prevented from being confounded with iron, by using an acid along with a sulphuret, under which circumstances the lead will give a precipitate but the iron none. (*See Lead.*)

On account of the de-oxygenating property of sulphuretted hydrogen in any form, with regard to iron, it always happens that the acid solutions of this metal that contain or are in contact with sulphuretted hydrogen pass to the state of *sub-oxydated* salts, the red sulphat for example changing to the green sulphat, the red muriat to the pale muriat, and the like. Also if a little of the perfect or red oxyd of iron be thrown into a bottle of sulphuretted hydrogenous water, and well shaken, the smell of sulphur is speedily overcome, and the oxyd becomes black and more voluminous than before, and if collected and thrown upon a red-hot iron it gives out a strong sulphureous smell and blue flame, and if treated with muriatic acid it gives out sulphuretted hydrogen.^a In this experiment therefore the sulphuretted hydrogen is decomposed, the hydrogen appearing to be employed in partially deoxygenating the oxyd, and the sulphur afterwards uniting with it into a hydro-sulphuretted sub-oxyd of iron.

Iron readily unites with phosphorus, forming the phosphuret of iron. This may be prepared according to Pelletier in two ways, either by the direct union of iron and phosphorus, or by a mixture of phosphoric acid, charcoal, and iron. In the latter method this ingenious chemist mixed one ounce of vitreous phosphoric acid, one ounce of iron turnings, and a dram of charcoal, and melted them with a full heat for some time in a covered crucible, and the result was a harsh white granular button, partly crystallized in rhomboidal prisms, which was phos-

phuret of iron mixed with some phosphat. Another method adopted was to add sulphat of iron in solution to human urine, which gave a precipitate of phosphat of iron. An ounce and a half of this precipitate, mixed with two drams of charcoal powder, two drams of calcined borax, and as much glass, and melted in a strong heat, gave a button of phosphuret of iron weighing two drams. This phosphuret put on a muffle in the midst of the coals, soon melted, and on the surface small jets of phosphoric flame were seen, owing to the phosphorus burning off. An ochery porous mass remained. Iron may also be combined with phosphorus, according to the same chemist, simply by mixing equal parts of vitreous phosphoric acid and iron. In this process a portion of the phosphoric acid yields its oxygen to a portion of the iron, and the phosphorus resulting thence unites with that part of the iron which is left metallic, and settles at the bottom of the crucible as phosphuret of iron, whilst the remaining phosphoric acid and oxyd form a black vitriform scoria on the surface.

The same chemist also projected small pieces of phosphorus on red-hot iron filings, which both together immediately melted down into a very hard white striated button of phosphuret of iron that was still magnetical. The surface was covered with a black vitrescent scoria, most of which soon run through the crucible.

The phosphuret of iron thus produced contained about 20 per cent. of phosphorus.

Iron when metallic is not sensibly affected by oils or any oleaginous substances, but on the contrary, these when fresh preserve iron from rusting by exposure to air. But when the oils grow rancid the iron itself oxydates from this cause. A composition of hog's lard and a little camphor thickened with black-lead is said to preserve iron from rusting better than most other greasy compositions.

The oxyds of iron dissolve in oils, giving them a reddish-brown colour. A very intimate combination of oil and oxyd of iron is produced by adding a solution of soap to a solution of sulphat or any other salt of iron. This soon hardens to a very stiff pasty mass.

The alloys of iron actually employed in the arts are very few, but this metal will combine more or less easily with most of the other metals. The amalgamation with mercury has generally been thought impracticable, but they may be made to combine by a method that will be mentioned under that metal.

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The few observations to be made on the different alloys of iron will all be described under the other metals respectively, except the manufacture of *Tin-Plate*, which may be here mentioned.

Tin-Plate or *Tinned Iron* (*Fer Blanc* of the French) holds an intermediate place between an alloy and a coating. It is made simply by immersing plates of iron into melted tin, whereby they not only become covered with a perfect coating of this metal, but a very intimate union of the two metals takes place, to a certain depth in the substance of the iron, which is seen by cutting it transversely, and when the tinning has been repeated two or three times the whole plate is more or less alloyed, or as it were soaked with the tin.

Tin-plate is manufactured in several countries, but no where to such perfection as in England, to judge by the quantity exported. The finest kind when highly polished has a lustre and whiteness scarcely inferior to silver, and the peculiar excellence of the English plate appears to be chiefly owing to the perfect smoothness given to the plate before tinning, and the great uniformity in the application of the metallic coating.

The general process is extremely simple, and is thus described by Mr. Donovan.*

It is carried on near Caermarthen in South Wales, the centre of an immense and increasing manufacturing district of many of the most important metals.

The iron ore employed in this manufactory is the common kind of the country, intermixed with a large portion of the fine hæmatite from Ulverstone in Lancashire, which gives a very fine metal. This too is smelted with charcoal instead of coke, to produce a metal of the greatest purity and extensibility, and closeness of texture, which qualities are particularly required in this manufacture. The reduced ore is smelted in the usual manner and cast into pigs, which are then wrought by the hammer into long flat bars, that are afterwards cut into pieces of about ten inches in length. These are then wrought into plates by being heated red-hot, and passed through a flattening-mill which consists of two large cylinders of steel, case-hardened and secured in a frame of iron. These are placed contiguous to each other but with a certain interval of space, and revolve in a contrary direction, so that when one end of the bar is thrust in the space between the cylinders, the whole is drawn through and pro-

portionably extended and flattened in the passage. The distance between the cylinders, which of course determines the thickness of the plate, is maintained and regulated by screws which can be altered at pleasure. When the bar is thus made into a plate of twice the thickness of the ordinary plates it is heated red-hot, cut in two by a pair of shears, and one piece folded exactly over the other, and both repassed repeatedly through the cylinders till the folded plate has extended to the same length and breadth as the plate was before cutting. It is then clipped round the edges and the two plates torn asunder (which requires some little force) after which they are each finished by passing through a finer rolling-press, so as to take away every crease or inequality in the plate, and those that are too rough to pass through this finer press are thrown aside.

The plates are then steeped in a very weak acid liquor, and when taken out are scoured thoroughly with bran so as to be quite bright and polished to enable the tin to adhere. The tin is melted in deep rectangular crucibles, and kept fluid by a moderate charcoal fire beneath. To prevent its calcination a quantity of grease prepared from linseed-oil and suet is constantly kept floating on the surface of the tin and renewed as it evaporates off, which gives an excessively nauseous stench. The plate is then taken up by one corner by a pair of pincers and dipped vertically into the tin, and when withdrawn is found beautifully white and resplendent with the coating of this metal that adheres to it. This dipping is repeated three times for what is called *single tin plate*, and six times for the *double plate*. The plates are then only cleansed and sorted, and are fit for use.

Some further particulars may be added from other authorities.

In many manufactories the iron plates before tinning are cleansed by being immersed in large barrels full of a mixture of rye-flour and water, sometimes with verjuice which by fermentation has become very acid. In Bohemia² the plates remain three times twenty-four hours in tubs filled with this acedent mixture, in three different states, after which they are washed, scoured with sand and water, and kept under water till just before they are used, to avoid rusting again.

Attention is to be paid to the heat of the melted tin; if too hot, the plate comes out yellow. The plates are immersed quite wet into the melted tin, passing in their way through

* Descriptive Excursions through South Wales in 1805, vol. 2, p. 194.

² Jars Voy. Min. 6 Mem

the melted suet which covers it. Just before dipping, some water is thrown on the melted suet, which causes a violent ebullition and makes the surface of the metal quite clean and bright. The plates when tinned are set up to drain, by which a number of drops of tin collect in small knobs at the lower part. These are taken off by a second immersion into a separate cauldron of tin, but only to the depth of a few inches, by which the drops of tin melt down and the whole tinning is made more uniform in thickness. They are then cleansed with a rag and saw-dust or bran. About $19\frac{1}{2}$ pounds of tin are required for 300 plates, measuring 1 foot by 9 inches.^a

The manufacture of tin-plate in France appears to be conducted so nearly in the same manner as not to require a separate description.

In the manufactures of tin-plate on the continent a quantity of copper is always added to

the tin, but in very small proportion. The exact quantity is regulated by slight circumstances, which only experience can teach. It appears to be in general from $\frac{1}{80}$ to $\frac{1}{120}$ of the tin. The copper prevents the tin from adhering in too great a quantity to the iron, and causes the superfluous part to drain off more freely. Too much copper gives a dull yellow tint.

It appears that the method of flattening the bar into plate by cylinders is only adopted in this country, but in other places is done by the hammer.

The affinities of the oxyd of iron for the respective acids are in the following order: the gallic, oxalic, tartareous, sulphuric, muriatic, nitric, phosphoric, arsenic, fluoric, succinic, citric, acetic, boracic, prussic, and carbonic acids.

ISERIN. See TITANIUM.

ISINGLASS. See GELATIN.

^a Encycl. Arts & Metiers. art. Ferblantier.

END OF THE FIRST VOLUME.

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ACANTICONE. See AMPHIBOLE.

ACETIC ACID. ACETITES. VINEGAR.

M. Cadet^a has made several experiments on the manufacture of sugar-vinegar and the best proportions of ingredients. It is well known that pure sugar dissolved in water will not ferment by itself, but if yeast or leaven be added, fermentation is soon established, at first vinous, afterwards acetous. Mucilage, Extract, Fecula contributed materially to the products of fermentation, but M. Cadet has apparently been compelled in order to simplify the enquiry, to pass over very slightly the effects of these substances, and to confine himself to the operation of sugar alone. His results therefore can only be considered as affording some approximation to accuracy. To form a simple sugar vinegar he gives the following as the best proportions.

Sugar	12.4.
Leaven or Yeast . .	8.
Water	86.8
	100.0

When a much greater proportion of sugar is added, a portion of it escapes fermentation, and may be procured from the vinegar unaltered. Though alcohol is the leading product of the vinous fermentation, and therefore (*ceteris paribus*) the more alcohol a fermented liquor contains, the greater quantity of acetous acid it will produce, yet the addition of alcohol to the fermenting liquor will not encrease the product of acetous acid, and if more than about $\frac{1}{17}$ of

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alcohol be added, the fermentation is entirely stopped and no vinegar is formed.

In making vinegar in the large way, from whatever vegetable material, whether wine, cyder, grain, carrots, sugar, &c. M. Cadet advises a previous essay of about 8 ounces of the material (if dry) with 3 pounds of water and $\frac{1}{2}$ oz. of yeast fermented completely into vinegar. To this is to be added gradually a solution of caustic potash of known strength, till the liquor is saturated (as determined by litmus, &c.) and the quantity of solid potash noted. Then for every part of potash used he estimates 1.268 parts of sugar to have been acidified by the fermentation, and hence the saccharine strength of the materials is found. Then to produce the strongest possible vinegar without leaving any undecomposed sugar, he proposes so much sugar to be added to the materials (if deficient in this principle) as will raise the proportion to 12.4 per cent. of the whole fermenting mass, which (with the 0.8 per cent. of leaven) produces as above mentioned the most favourable proportions for this manufacture.

The density of acetic acid cannot be depended on singly as any indication of the *strength* of acidity. On this subject M. Mollerat has some valuable observations.^b The strongest acetic acid that he could obtain, which was quite pure and free from empyreuma, had the specific gravity of 1.063 at 60° Fahr. This was highly volatile when moderately heated, and entirely congealed at about 55°, and did not thaw at 72°. A given portion of it saturated 250. of carbonat of soda, and its proportion of real acid

per cent. of sulphur, and therefore it is lost somewhere between 46 and 52 per cent. of sulphuration.

The alkaline sulphurets have little if any action on iron but dissolve its oxyd, and acquire thereby an intense green colour, which the affusion of an acid immediately destroys.

Sulphuretted hydrogen added either in gas or in a liquid form to any solution of iron, first deoxygenates it entirely or partially, and then forms a black precipitate of hydro-sulphuret of iron. This precipitate is however resolvable in most acids, or may be prevented from forming by previously acidulating the solution, in which respect it differs from the hydro-sulphuret of lead; and hence in examining wines and other liquors supposed to contain lead, this metal is prevented from being confounded with iron, by using an acid along with a sulphuret, under which circumstances the lead will give a precipitate but the iron none. (*See Lead.*)

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Iron readily unites with phosphorus, forming the phosphuret of iron. This may be prepared according to Pelletier in two ways, either by the direct union of iron and phosphorus, or by a mixture of phosphoric acid, charcoal, and iron. In the latter method this ingenious chemist mixed one ounce of vitreous phosphoric acid, one ounce of iron turnings, and a dram of charcoal, and melted them with a full heat for some time in a covered crucible, and the result was a harsh white granular button, partly crystallized in rhomboidal prisms, which was phos-

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ACANTICONE. See AMPHIBOLE.

ACETIC ACID. ACETITES. VINEGAR.

M. Cadet^a has made several experiments on the manufacture of sugar-vinegar and the best proportions of ingredients. It is well known that pure sugar dissolved in water will not ferment by itself, but if yeast or leaven be added, fermentation is soon established, at first vinous, afterwards acetous. Mucilage, Extract, Fecula contributed materially to the products of fermentation, but M. Cadet has apparently been compelled in order to simplify the enquiry, to pass over very slightly the effects of these substances, and to confine himself to the operation of sugar alone. His results therefore can only be considered as affording some approximation to accuracy. To form a simple sugar vinegar he gives the following as the best proportions.

Sugar	12.4.
Leaven or Yeast . .	8.
Water	86.8
	—
	100.0
	—

When a much greater proportion of sugar is added, a portion of it escapes fermentation, and may be procured from the vinegar unaltered. Though alcohol is the leading product of the vinous fermentation, and therefore (*ceteris paribus*) the more alcohol a fermented liquor contains, the greater quantity of acetous acid it will produce, yet the addition of alcohol to the fermenting liquor will not encrease the product of acetous acid, and if more than about $\frac{1}{17}$ of

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alcohol be added, the fermentation is entirely stopped and no vinegar is formed.

In making vinegar in the large way, from whatever vegetable material, whether wine, cyder, grain, carrots, sugar, &c. M. Cadet advises a previous essay of about 8 ounces of the material (if dry) with 3 pounds of water and $\frac{1}{2}$ oz. of yeast fermented completely into vinegar. To this is to be added gradually a solution of caustic potash of known strength, till the liquor is saturated (as determined by litmus, &c.) and the quantity of solid potash noted. Then for every part of potash used he estimates 1.268 parts of sugar to have been acidified by the fermentation, and hence the saccharine strength of the materials is found. Then to produce the strongest possible vinegar without leaving any undecomposed sugar, he proposes so much sugar to be added to the materials (if deficient in this principle) as will raise the proportion to 12.4 per cent. of the whole fermenting mass, which (with the 0.8 per cent. of leaven) produces as above mentioned the most favourable proportions for this manufacture.

The density of acetic acid cannot be depended on singly as any indication of the *strength* of acidity. On this subject M. Mollerat has some valuable observations.^b The strongest acetic acid that he could obtain, which was quite pure and free from empyreuma, had the specific gravity of 1.063 at 60° Fahr. This was highly volatile when moderately heated, and entirely congealed at about 55°, and did not thaw at 72°. A given portion of it saturated 250. of carbonat of soda, and its proportion of real acid

^a An. Chim. tom. 62.

^b Ibid. 68.

was reckoned at 87.125 per cent. A mixture of the same acid and water in a certain proportion was made, which had exactly the same specific gravity, but its saturating power was only equal to 118 of carbonat of soda, or 58.725 real acid. A further addition of water to this last acid *diminished* the density as well as the saturating power, and this continued uniformly in every subsequent proportion of water added. On the other hand the first addition of water to the concentrated acid of 1.063 sp. gr. *encreased* the specific gravity, though the proportion of real acid was of course diminished. Hence there must be a point of the maximum of specific gravity in which the gravity would be lessened both by encreasing and diminishing the real strength of the acid as measured by its saturating power. This maximum of density M. Mollerat estimates at 1.0791 sp. gr. and 67.256 per cent. of real acid.

The observations of M. Derosne, M. Berthollet and Mr. Chenevix, which we shall presently mention, confirm this fact of a maximum density existing in this acid in a certain state of dilution. These observations however only apply to the acetic acid or *radical vinegar* obtained from some of the neutral acetates. The common distilled vinegar contains a quantity of carbonaceous matter which can only be separated by combining it with a basis and redistilling it.

Mr. Chenevix^e has given a valuable experimental essay on acetic acid and some of the acetates. A quantity of acetite of copper was distilled *per se*, and the product separated as it came over into different portions. The first portion had the specific gravity of 1.0659, and the proportion of real acid estimated from its saturating power was 62.971. The second was 1.058 sp. gr. and 67.461 acid: the third, 1.0454 sp. gr. and 74.411 acid; the fourth, 1.040 sp. gr. and 73.295 acid.

Though these numbers do not exactly correspond with those of M. Mollerat, they shew that the specific gravity of acetic acid is no indication of its strength in real acid, and the reason of this is supposed to be the admixture of a portion of an inflammable spirit in various proportions formed during the distillation of the acetites, which has been examined by various chemists, and which the author terms *Pyro-acetic Spirit*; and M. Derosne, *Pyro-acetic Ether*.

The products of the distillation of the metallic, alkaline and earthy acetates differ remark-

ably in the proportions of the acid, pyro-acetic spirit, and gaseous products, though the acetates themselves are all prepared with the same acetic acid. Hence it becomes an interesting enquiry to examine what is the action of these bases on the acid during distillation, which can explain this great difference in the products. The analysis is complicated and attended with many difficulties, but the experiments of Mr. Chenevix on this subject deserve notice. The metallic acetates examined were those of silver, copper, nickel, lead, iron and manganese. A given quantity of each was distilled from a luted earthen or glass retort according to the heat required, to which was attached a tubulated matrass to collect the liquid products, a Woulfe bottle holding a solution of pure barytes, and a pneumatic trough. The heat was kept up as low as possible to effect the decomposition. The results consisted therefore of three substances which required a subsequent examination, namely, the metal or metallic oxyd left in the retort, the liquid, and the gaseous products. The metallic residue was reguline in some cases and oxidated in others, and mixed with a small portion of charcoal which was separated by dissolving the metal.

The liquid product was examined in relation to its specific gravity, its acidity, and the quantity of pyro-acetic spirit. The force of acidity was measured by the quantity of a solution of pure potash saturated by a given portion of the acid. It was more difficult to separate the pyro-acetic spirit. When alcohol is mixed with any watery liquid, the usual mode of detecting it is by the addition of carbonate of potash, but where the liquid also contains an acid which by union with potash forms a salt soluble in alcohol, this mode of separating the spirit will not answer. It was therefore necessary in the present instance to redistill from potash the liquid products of some of the acetates, and thus deprive them of their acid, before the spirituous portion could be obtained. We shall add the results of these experiments as far as concerns the liquid product in the three circumstances of specific gravity, acidity and spirit.

	Sp.Gr.	Acidity	Spirit
Acetite of Silver .	1.0656	107.309	0.
Acetite of Nickel .	1.0398	44.731	2.
Acetite of Copper .	1.0556	84.868	0.7
Acetite of Lead .	.9407	3.045	0.555
Acetite of Iron .	1.011	27.236	0.24
Acetite of Zinc .	.8452	2.258	0.695
Acetite of Manganese .	.8264	1.285	0.94

Of these acetites the metallic bases of the four first were left after the process in the reguline state, the iron was the black oxyd, the zinc the white oxyd, and the manganese the brown oxyd. The enormous difference in strength of acidity which these products shew, must immediately strike the reader. The author inclines to the opinion that in proportion to the greater difficulty of the reduction of the metallic base is the quantity of spirit yielded and of acid destroyed. Thus the acetite of silver which is reduced with the greatest ease, gives an acid of much greater strength than the others, but no ascertainable quantity of spirit. On the other hand the acetite of lead, which is reduced with more difficulty, and the acetite of zinc which is not reduced at all, give a very weak acid but more spirit. It must be acknowledged however that the production of spirit bears no proportion to the destruction of acid, so that no argument can be hence derived of the conversion of the latter into the former.

When the acetites of potash and of soda are distilled *per se*, they yield a more spirituous and less acid product than any of the metallic acetites. The product from dry acetite of barytes had the specific gravity of only .8458, did not redden vegetable colours, but contained so concentrated a spirit that it was necessary to add water to enable carbonat of potash to produce any separation of spirit, and then the quantity of spirit separated was more in bulk than the entire original product of the distillation. Hence the spirit was in a more condensed state before, than after the separation. Mr. Chenevix has found the acid product distilled from acetited silver to contain the purest and strongest acetic acid and the least mixed with spirit. Its specific gravity was 1.0656 when undiluted, and its saturating power estimated at 107.309. When gradually lowered by water, the specific gravity at first *increased* to 1.0733, but after this point again *diminished* by every subsequent dilution. This anomaly in the change of specific gravity cannot be accounted for *here* by the presence of pyro-acetic spirit, since none was detected, and the author therefore ingeniously attributes it to the strong tendency of crystallization at a moderate temperature, which this very concentrated acid possesses, and which probably acts as it does with water to produce an expansion of the liquid as it cools down to its point of congelation. The fact of the ready crystalli-

zation of the acid is undoubted, and this appears not to be owing to the presence of any spirit or extraneous matter, but rather to depend on the degree of concentration of the acid itself.

It has been maintained by some chemists that prussic acid and ammonia are among the products of the distillation of the acetates. This however is denied both by Mr. Chenevix and by Tromsdorff. The latter chemist^d distilled acetite of soda, acetite of lead and acetite of potash, separating the volatile portion from the residue. The former was passed through an ignited tube, and carbonic acid, carburetted hydrogen and empyreumatic oil were produced, but no prussic acid nor ammonia appeared either in this or in the fixed residue.

The latest analysis of acetic acid that we possess, is one of a very interesting series on various animal and vegetable substances, performed by Messrs. Gay-Lussac, and Thenard.^d The mode of analyzing is original, being by combustion with oxymuriat of potash, as will be further described under the article ANALYSIS. The acetic acid was procured from acetite of potash by sulphuric acid, without any artificial heat, and the acid obtained was quite free from any admixture of the sulphuric. It was first boiled with carbonat of barytes, and the resulting acetite of barytes dried in the heat of boiling water. Thirty grammes of this salt were dissolved in water and decomposed totally by sulphat of ammonia, and the sulphat of barytes, when ignited, weighed 25.445 grammes, of which the barytes, according to the received proportions, forms 67 per cent. and hence the composition of the acetited barytes dried at a boiling water heat, is 43.17 per cent. of acetous acid, and 56.83 barytes.

This acetite was then ignited with oxymuriat of potash, and the acetic acid when reduced to its ultimate elements, carbon, oxygen, and hydrogen, gave the following proportions:

Carbon 50.224, oxygen 44.147, hydrogen 5.629.

Or, supposing all the hydrogen to be united to its saturating proportion of oxygen to constitute water, the result will be,

Carbon 50.224, water 46.911, oxygen in excess 2.865.

Four other vegetable acids were analyzed by these chemists in the same manner, namely, the oxalic, the mucous, the tartaric, and the citric, and the general results are as follow :

^c An. Chim. tom. 58.

^d Recherches Physico-Chimiques, &c. tom. 2.

	Oxygen in each.	Carbon.	Water.
Oxalic	50.56 —	33.57 —	22.87
Mucous	36.15 —	33.69 —	30.16
Tartaric	20.71 —	24.05 —	55.24
Citric	13.44 —	33.81 —	52.75
Acetic	2.87 —	50.22 —	46.91

These analyses, if correct, give a totally different idea of the constitution of the acetic acid, compared with the other vegetable acids, from that usually entertained. It has been maintained by Westrumb, Hermbstaedt, Crell, and others, that the pure acid of vinegar was the ultimate term of oxygenation of all the vegetable acids, so that any other of these could be converted into the acetic by an oxygenating process. Thus Hermbstaedt converted the dry acid of tartar entirely into the acetous, by distillation with manganese and sulphuric acid. (*See article Acetous Acid, Ch. Dict. vol. 1, p. 4.*) But on the other hand the above experiments of Messrs. Gay-Lussac and Thenard shew that the acetic acid is by far the *least* oxygenated of the five vegetable acids here mentioned, but contains a much larger proportion of carbon, and hence one may expect the acetic acid to be among the *earliest* products of any acidifying process going on in vegetable matter. This, they maintain, is supported by actual observation, for the acetic acid is that into which all vegetable and even animal matter is the soonest changed, whether by distillation or the putrid fermentation, or by the action of the nitric and sulphuric acids. How, say they, should these changes take place (especially that of wine into vinegar) and no intermediate acid be found, if the acetic acid was the most oxygenated.

Pyro-Acetic Spirit. Pyro-Acetic Ether.

This substance having already been partially described in our account of Mr. Chenevix's experiments, and also having been previously examined by Derosne,* we shall here add some further notice of it. It is contained, as already mentioned, in the product of the distillation *per se*, of most of the acetites, and it is probably in many cases owing to the admixture of this spirit that the specific gravity of the distilled liquid is so much lessened as to counteract the increased density which would naturally arise from a great intensity of acid. M. Derosne obtained it in the following experiments, which were also undertaken as a general examination of the products in the usual way of preparing acetic acid. An earthen retort was filled with

41½ lbs. (French) of verdigris, and distilled *per se*, in a very gradual heat kept up for three days. The products were divided into four successive portions, each of which was kept separate. The first portion weighing 5 lbs. 10 oz. was weakly acid to the last, and of a slight blue colour.

The second was stronger and deeper coloured, and weighed 6 lbs. 4 oz.

The third, was still stronger and more blue, had a much more pungent smell, but rather empyreumatic. It weighed 7 lbs. 4 oz.

The fourth was slightly yellow, had a weak but very empyreumatic smell, and required a very strong heat to be expelled. It weighed 8½ oz.

The united weight of these four liquids was 20 lbs. 5 oz. and the cupreous residue in the retort weighed 13 lb. 14 oz. so that there was a deficiency of 7 lb. 5 oz. to make up the original weight of the verdigris employed.

A large quantity of gas was produced in the operation, the whole of which was made to pass through a separate bottle of distilled water before it escaped, to which it gave some acidity and a very disagreeable burnt flavour.

The four distilled products were again rectified and divided into successive portions, and by comparing the specific gravity of each with the power of saturating alkali, it was found that the second and third products, or those which were obtained at the middle of the first operation, were much the strongest in acid with the least specific gravity. This intermediate product being rectified at a gentle heat, gave a quantity of inflammable gas, and a light inflammable liquor, but still acid. To separate the acid, solid caustic alkali was added to it in small portions, keeping the vessel in cold water till the acid was saturated, when part of the acetited potash crystallized spontaneously, and a light yellowish liquor rose on the surface, which was carefully decanted and again rectified by distillation at a very gentle heat. The product of this last operation is the *Pyro-Acetic Ether*.

It is quite clear and colourless, its smell pungent, its taste hot and empyreumatic. It is lighter than alcohol, very volatile, and produces cold by evaporation. It is highly combustible, burning with a flame at first blue, afterwards yellowish white. After its combustion it leaves a carbonaceous stain, and if previously mixed with a little water and burned, the water remains slightly acid. It does not

* An. Chim. tom. 63.

red den litmus. When added to a solution of gold in nitromuriatic acid with a little dry muriat of lime, the Pyro-acetic ether rises to the surface with a fine golden colour. In all these respects this substance resembles the other ethers, but it differs from them in being miscible with water in any proportion.

Mr. Chenevix, in the memoir already mentioned, has examined this *Pyro-Acetic Ether* or *Spirit* with much care, and compared its properties with those of the true Acetic Ether. To obtain the Pyro-acetic Spirit, acetite of lead was distilled *per se*, in an earthen retort, and the products again rectified, and the spirit separated. Its properties are the following: It is perfectly clear and without colour; its taste burning and somewhat urinous; its smell somewhat resembling that of peppermint mixed with bitter almond. The specific gravity was at first .7929; but after rectification over muriat of lime, .7864. It burns with a white flame, leaving no residue. It boils at 130° Fahr. It mixes with water, alcohol, and the volatile oils, in every proportion; also in some proportions with the fixed oils when cold, and in every proportion when heated. It dissolves a little sulphur, more of phosphorus, and a large quantity of camphor. White wax and fat dissolve in it when hot, but a portion separates on cooling or on adding water. It dissolves a little caoutchouc which is separable again by water, and it renders a solution of gum arabic extremely turbid.

A further examination of this spirit by distillation with potash and with the mineral acids, shews some decided points of difference between the Pyro-Acetic Spirit and the Acetic Ether prepared by acetic acid and alcohol, but a fuller analysis is yet wanting.

Some chemists have attributed the production of an inflammable spirit during the distillation of the acetites to that portion of alcohol which all vinegar contains, and is derived from the vinous fermentation which always precedes the acetous. It is certain that when a large quantity of vinegar is distilled, the first portions contain a little alcohol intimately mixed with the acid. But this alcohol comes over at the first impression of heat, and certainly cannot be supposed to enter into the composition of those solid acetites (verdigris for example) that require long ebullition of the acid and metallic oxyd, and subsequent evaporation to crystallize. Yet it is from these solid acetites that the Pyro-acetic Spirit is prepared, and it rises only towards the middle and end of the distillation,

when a heat much greater than is required to volatilize alcohol has been kept up for a considerable time. This Pyro-acetic Spirit or ether therefore, is obviously a product of the decomposition of some of the component parts of the acetous acid itself, and not an adventitious admixture of alcohol derived from the previous fermentation.

For some further remarks concerning the true acetic ether, see the article *Alcohol* in this Appendix.

Acetate of Alumine.

Gay-Lussac has some valuable observations on this salt, which are particularly useful to the dyer and calico-printer, who employ a vast quantity of it. When a solution of acetited alumine is heated, it becomes turbid and deposits a great deal of alumine; but (what is very remarkable) all the alumine is gradually redissolved on cooling and agitation. A second heating will again cause the alumine to precipitate, and the liquor will again become clear when cold; and this may be repeated an indefinite number of times. In a neutral solution of acetited alumine (such as is made by the calico-printers, by mixing alum and acetited lead) the author found that the quantity of alumine separated by mere heat was nearly half the whole contents. After the alumine is deposited from the heated solution, the liquor remains with an excess of acid, and hence the necessity of using chalk to saturate this excess, which however is often an injurious addition on other accounts. Alum will prevent this separation of alumine by heat.

ACETIC ETHER and SPIRIT. See the preceding article and ALCOHOL.

ACIDS VEGETABLE. See ANALYSIS.

ACTINOTE. See AMPHIBOLE.

AEROLITE or Meteoric Stone.

That stony masses, sometimes solitary, sometimes in showers, have fallen on the surface of the earth from the upper regions of the atmosphere, is a fact, which, though distinctly and particularly testified both by ancient historians and more modern observers, had gained but little credit among philosophers previously to the last twenty years. On some particular occasions indeed the evidence adduced was so circumstantial and apparently unprejudiced that nothing but the supposed impossibility of the fact prevented its reception. In the meantime new facts bearing a perfect analogy with the preceding ones continued to accumulate, and with such overpowering evidence that all *a priori* arguments gave way before them, and

the existence of atmospheric or meteoric minerals is fully admitted.

In the article *native IRON*, among the ores of that metal, the reader may find a few details relative to this subject; and a reference to another article *STONES meteoric* which by some unaccountable oversight is wholly omitted. This omission it is the purpose of the present article to supply.

Without adverting to the testimony of Livy, of Pliny, and of other ancient authors, I shall confine myself to a brief enumeration of those aerolites which have either fallen within the last twenty or thirty years, or of which, though the date of their fall is considerably more ancient, specimens are still extant, many of which have of late been submitted to chemical analysis.

Those luminous bodies called meteors or fire-balls, which make their appearance at irregular intervals, traversing with an excessively rapid motion the upper regions of the atmosphere, and ultimately falling on the surface of the earth, appear to be one source of meteoric stones. They evidently consist of a central nucleus in such a state of softness or fluidity as to admit of considerable variations in its shape; sometimes a disruption of the nucleus takes place, accompanied by an explosion, and the two or three pieces into which the mass is thus divided proceed in the direction of their previous course without any apparent abatement of velocity. More usually however the explosion is so violent as to break and disperse the meteor, and the fragments immediately fall to the ground. Of these meteors some of the most remarkable and the best observed in modern times are the following. On the 21st of May, 1676, a meteor was observed by Montanari, professor of mathematics at Bologna, and by others, passing with great velocity across the north of Italy in a direction nearly from E. to W. When it had arrived over the sea to the S.W. of Leghorn it burst with a violent explosion, and its fragments, as they fell into the sea, produced a hissing noise like that occasioned by plunging red hot iron into water.

On the 11th November, 1761, a meteor was observed in several of the provinces of France. It burst with a loud explosion into a great number of fragments in the neighbourhood of Dijon, one of which fell upon a house and set fire to it.

On the 17th July, 1771, a meteor, traversing from N. to S. was observed in England and in France. It burst with a loud explosion S.W.

of Paris, causing a commotion like that of an earthquake. Its elevation above the surface of the earth, when first perceived, was more than 80,000 yards, but at the period of its explosion it had descended to about half its former elevation.

On the 18th August, 1783, a large meteor, traversing in the same direction as the preceding, was observed in various parts of England, of France, and of Italy as far as Rome. When it first was noticed, its apparent magnitude was about equal to that of the planet Jupiter, but it rapidly increased, and at the instant of its explosion was of greater apparent magnitude than the full moon. Its form varied from round to oblong, and an internal movement like that of ebullition was distinctly visible: it divided into several smaller masses, which continued in their onward course before the final explosion by which it was dissipated. The rate of its motion, according to the lowest estimate, was about $1\frac{1}{4}$ mile in a second.

The diameter of the nucleus of those meteoric bodies is variously estimated at from 100 to 1000 yards; and it is obvious that a body of much inferior size, moving with an equal or nearly equal velocity, would fail to attract notice, especially in the day time, except at the period of its actual explosion. The greater number of instances of the fall of meteoric stones are under circumstances which render it probable that they too are occasioned by the exploding of meteors, which their inferior magnitude alone prevents from being visible. A loud noise, like that of thunder or the firing of heavy artillery, or the overturning of a load of stones, sometimes with, often without any visible flash, is the first circumstance which attracts notice and excites alarm, then a hissing like the noise occasioned by the passage of a shot through the air is heard; a momentary glance of the falling bodies is caught, and they are perceived entering the surface of the soil, the grass and mould being at the same time thrown up on all sides, and a sulphurous odour diffusing itself to some distance around. On immediate search being made, by digging in the direction of these holes, there is found, at the depth of a foot or two, a black roundish stone, sometimes large sometimes small, often too hot to be held in the hand, and smelling strongly of sulphur. Such are the general phenomena; the most remarkable examples are as follow:

1. In the year 1492, according to Sebastian Brandt, there fell from the sky at Ensisheim in

Upper Alsace, a large somewhat oval stone, which from this extraordinary circumstance was kept attached to a chain in the cathedral of that place. The weight of the stone was about 2 cwts. externally it was rough, dull, and of a dark colour. On being broken, it presented a close grained texture and a blackish-grey colour, and contained interspersed confusedly crystallized grains of yellow pyrites, and of grey scaly non-sulphurous iron ore attractable by the magnet, and therefore approaching to the metallic state. The specific gravity of the stone was 3.2: it did not give sparks with steel, and was pulverized without difficulty. It was analyzed by professor Barthold in the year 1797, but this analysis being performed on the entire stone, and not separately on the three substances of which it visibly consists, we can only gather from the result, that it consists of silex, alumine, magnesia, iron, sulphur and a little lime. The conclusion of the professor is, that the stone of Ensisheim is a common argillo-ferruginous mineral, and that its traditionary origin is a mere superstitious fiction.

2. On the 3d July, 1753, a shower of stones, each weighing from one to twenty lbs. and upwards, was said to have fallen during a thunder-storm at Plann near Tabor in Bohemia. One of these was deposited by Baron Born in his cabinet and described in his *Lithophylacium* pt. I. though he considered the account of their origin to be an idle story; and the cabinet of Baron Born coming into the possession of Mr. Greville, the specimen in question was found to form a part of it.

3. On the 20th of August, 1789, a stone 15 inches in diameter fell near Roquefort in the Landes, during the explosion of a meteor. It broke through the roof of a cottage and killed a herdsman and some cattle.

4. In the following year a shower of stones fell in Armagnac.

5. On the 12th July, 1794, about a dozen stones of various weights and dimensions fell in the neighbourhood of Sienna, in the midst of a most violent thunder-storm, at the feet of several persons, men, women, and children. They fell about eighteen hours after the enormous eruption of Mount Vesuvius, but at a distance of at least 250 miles from that volcano. One of the largest of these stones weighed upwards of five lbs. and a piece of this was brought by Sir Wm. Hamilton to England.

6. On the 17th December, 1795, a stone weighing 56 lbs. was seen by several persons to fall near Wold Cottage, in Yorkshire: as it fell a number of explosions were heard. It penetrated through twelve inches of soil and six inches of solid chalk-rock, and in burying itself had thrown a large quantity of earth to a great distance; when the stone was dug out it was warm, smoked, and smelt strongly of sulphur. The stone itself was exhibited in London, and a piece of it was procured by Sir Joseph Banks.

7. On the 19th December, 1798, about eight o'clock in the evening, the sky being perfectly without clouds, a luminous meteor was observed by the inhabitants of Benares in India, and of the parts adjacent, accompanied by a loud noise resembling irregular platoon firing. At a village about 14 miles from the city the natives were alarmed not only by the light and the thundering noise, but with the sound as of heavy bodies falling through the air, and the roof of one cottage was actually broken through by a stone weighing above two lbs. which buried itself to the depth of several inches in the consolidated earth of which the floor was formed. The next morning the inhabitants perceived the ground to be pierced and turned up in various places, and in these on digging to the depth of some inches they found stones perfectly similar in external appearance to that which had forced its way through the roof of the hut. They were of various sizes, from about three inches to upwards of four in their largest diameter. Some of these, with a detailed account of the circumstances above related, were transmitted to England in the following year.

Thus there happened to be at the same time in England specimens from four different parts, viz. from Bohemia, from Sienna, from Benares, and from Yorkshire, of stones said to have fallen from the sky. The date of three at least of these analogous events, was so recent and the circumstantial and direct testimony in their favour was so powerful, that the narrations however extraordinary and however they might separately have been discredited, could not fail of exciting a degree of attention proportioned to their importance. One of the consequences of this was a chemical examination of these four specimens by Ed. Howard, Esq. F.R.S.* and an accurate description of their external characters and physical properties by Count Bournon.

* Phil. Trans. 1802.

The stones from Benares are covered with a thin crust of a deep black colour, without any lustre, and sprinkled over with small asperities which cause it to feel like fish-skin. Internally they are of a greyish ash colour, and of a granulated texture, like that of a coarse grit-stone. They are evidently composed of four different substances. One of these (and that which forms the greatest part of the entire mass) is in the form of distinct concretions, more or less globular, varying in magnitude from the size of a small pin's head to a pea: their colour is grey, inclining more or less to brown, and they are perfectly opaque. They are easily frangible in all directions, and display a compact conchoidal fracture with a slight degree of lustre resembling enamel, the hardness is about equal to that of glass, and they give a few feeble sparks with steel. Another of the substances is reddish yellow iron pyrites, which when pulverized becomes black; it is not attractable by the magnet, and is irregularly dispersed through the substance of the stone. The third substance is iron in minute particles, and perfectly malleable: its proportion to the whole, as estimated from pulverizing the stone and separating the iron by means of a magnet, is about 2 per cent. These three substances are held together by a fourth, which is soft, of an earthy consistence, and a grey colour. The black crust by which the surface of the stone is coated, although of inconsiderable thickness, affords bright sparks when struck with steel, and appears to consist principally of magnetic black oxide of iron. The specific gravity of the entire stone is 3.35.

The stone from Yorkshire presents similar constituent parts with that from India, with the following exceptions. The distinct concretions are smaller, and of a more irregular figure. The proportion of iron pyrites is less; that of the metallic iron is considerably greater, amounting to 8 or 9 per cent. and the iron itself instead of being in minute distinct grains was in irregularly shaped pieces, some of which weighed several grains. The earthy part of the stone has rather more consistence than that of the former specimen, and greatly resembles in appearance decomposed felspar or kaolin. The specific gravity of the stone is 3.5.

The stone from Sienna was black externally, and internally was coarsely granular like the specimen from Benares. Its specific gravity was 3.41. In it might be perceived the same globular concretions, the same kind of iron pyrites, and the same grains of metallic iron,

the proportion of this last somewhat exceeded that afforded by the specimen from Benares. The same kind of grey earthy substance served to connect the different parts together. But, beside the ingredients above mentioned, there were a few globules of black magnetic oxide of iron, and a single globule of a pale greenish-yellow colour; this latter was completely transparent, had a perfectly vitreous lustre and fracture, and in hardness was rather inferior to calcareous spar.

The stone from Bohemia greatly resembles that from Yorkshire. In it may be observed the same grey substance both in globular and irregular concretions, also the same particles of metallic iron, and the same kind of earthy substance connecting together the other parts. It differs however from the others in the particles of pyrites being so small as not to be visible without the help of a lens; and in the proportion of metallic iron amounting to about 25 per cent. of the entire mass. Its specific gravity was 4.28.

The ingredients being the most distinct in the specimen from Benares, was the inducement to Mr. Howard to commence his chemical examination with this. Some pieces of pyrites to the amount of 16 grains being carefully picked out from among the other substances were digested at a low heat with diluted muriatic acid. A small quantity of sulphuretted hydrogen was disengaged, and after a time all that remained undissolved was earthy matter to the amount of two grains (thus reducing the real quantity of pyrites operated on to 14 grs.) and about 2 grains of sulphur. The solution was saturated with ammonia, upon which a precipitation of oxide of iron took place, and the supernatant fluid acquired a violet purple colour; this latter, having previously been found to contain not copper but nickel, was decomposed by sulphuretted hydrogen. The oxide of iron after ignition weighed 15 grains, and the sulphuret of nickel being reduced to an oxide by calcination weighed something more than one grain. From these data Mr. Howard considers the pyrites as composed of $10\frac{1}{2}$ iron, 1 nickel and 2 sulphur, estimating the per-oxide of iron to contain 55 per cent. of metal. On examination however it appears that certain difficulties or mistakes adhere to these results, which make the analysis by no means so correct as it appears to be. First, Mr. H. from his own experiments states that 100 parts of iron afford 145 grains of oxide by solution in muriatic acid precipitation by ammonia, and sub-

sequent ignition, hence this oxide contains 70 per cent. of metal, but by the concurrence of Proust, Davy, Thomson, Berzelius and all the best authorities, the per-oxide of iron contains about 52 per cent. of metal, and the protoxide 73 per cent. ; hence it is evident that Mr. Howard's oxide was a mixture of the two, and was not sufficiently calcined. Secondly, allowing with Mr. H. that the real quantity of iron was 10.5 grains, this when combined with sulphur in the only two proportions in which it is capable of combining, would produce 16.5 grains of magnetic pyrites, or 21.5 of the common kind. Again, there is the distinct testimony of Count Bournon that the pyrites was not magnetic, and the equally distinct testimony of Mr. H. that it was decomposable by muriatic acid, and that a little sulphuretted hydrogen was at the same time evolved. But of the two known kinds of pyrites the magnetic alone is decomposable by muriatic acid with evolution of sulphuretted hydrogen. We must therefore either suppose some error in the analysis, or that the pyrites in question differs essentially from the only two that chemistry as yet acknowledges. In either case all that can be concluded from the analysis is the presence of much iron, of a little sulphur, and of less nickel.

After examining the pyrites Mr. H. undertook the analysis of the metallic iron of the aerolite, which being treated in the way already described in the article IRON, appeared to be an alloy of about 17 parts iron and 6 nickel.

The globular concretions were then analysed by fusion with potash in the usual way and afforded

50 sillex
15 magnesia
34 oxide of iron
2.5 oxide of nickel

101.5

Lastly, the earthy matter, which served as a cement for the three other ingredients, was examined in the same manner as the globular concretions were, and yielded

48 sillex
18 magnesia
34 oxide of iron
2½ oxide of nickel

102.5

The excess in both these analyses is no doubt to be attributed to the difference of oxydation of the iron as existing in the substance and as obtained by analysis.

The component parts of the stones from Sienna, from Yorkshire, and from Bohemia, being in too small grains to allow of their separation with sufficient exactness, a small portion of each specimen was pulverized and examined in the usual way. They all afforded sillex, magnesia, the oxides of iron and of nickel, and nothing else ; thus exhibiting a perfect analogy with each other and with the aerolite from Benares.

It deserves to be remarked how striking a resemblance as to their component parts exists between the earthy parts of these aerolites, and the granular peridot or olivine which is almost peculiar to basalt ; this substance being composed according to Klaproth of

50 sillex
38 magnesia
12 oxide of iron

It is further worthy of notice that the external characters of the small transparent globule found in the stone from Sienna for the most part agree with those of the transparent globules that occur in the cells of the supposed meteoric iron from Siberia ; and that these are also strikingly similar to those of olivine.

It remains to take some notice of a few other aerolites of still more recent origin, and which have exhibited certain peculiarities in their analysis.

8. On the 12th of March, 1798, the air being calm and without clouds, the inhabitants of Valence, in the Lyonnais, and its neighbourhood, were alarmed with the appearance of a meteor, accompanied by a singular noise, and exhibiting partial explosions. It was seen to fall in a vineyard, and on the day after, when the terror of the peasants had in a degree subsided, an officer of the police being present, search was made in the vineyard, a recent irregular hole of the depth of about 20 inches presented itself, at the bottom of which was found a black stone weighing above 20 lbs. On being broken it appeared to be composed of a granular ash-grey earthy matter, in which were imbedded grains of metallic iron, and of pale reddish yellow pyrites, with globular concretions of a grey colour, and some small irregular masses of a substance resembling olive coloured

steatite. A portion of the entire stone being analysed by Vauquelin afforded

- 46. silex
- 15. magnesia
- 2. lime
- 38. oxide of iron
- 2. oxide of nickel

103.

9. On the 26th of April,^a 1803, about one o'clock in the afternoon, the air being calm and only a few clouds floating in the sky, a brilliant meteor was observed moving rapidly from S. to N. in the vicinity of the town of l'Aigle, in Normandy. In a few seconds afterwards there was heard at l'Aigle, and all around to the distance of even 90 miles radius, a violent explosion which lasted five or six minutes: this was succeeded by three or four bursts like the discharge of cannon, and by a number of smaller explosions like musket firing, the whole being terminated by a noise like the roll of a prodigious drum. These sounds evidently proceeded from a small cloud which appeared to be nearly stationary during the whole time, and the vapours of which it was composed were thrown out on all sides during each explosion. The inhabitants of the district immediately under the cloud were also alarmed by the hissing noise as of stones discharged from slings, and at the same time a multitude of masses of solid matter were observed to fall to the ground. The area upon which these stones fell is an irregular ellipse about 7 miles long by 3 miles wide; the largest stones were found at the S. Eastern extremity of this space, the smallest ones at the opposite extremity, while the middle-sized occupied the middle of the area. The size of the stones varied from 18lbs. to a quarter of an ounce: their number could not be ascertained, but they certainly amounted to some thousands. They were so hot when they fell as to burn those who attempted to take them up, their odour was sulphureous, or rather like that arising from the discharge of gunpowder. In their external characters, and as far as can be judged from a coarse analysis of them by M. Sage, they bear a close analogy to those which have been already described.

10. On the 15th of March, 1806,^b a loud explosion with a roll like thunder was heard at Valence Dept. Du Gard, and immediately afterwards a stone weighing about 4 lbs. was observed to fall; in its descent it broke a

branch of a fig-tree and buried itself a few inches in the soil, (at the same time another stone of the weight of eight or nine lbs. was observed to fall in the adjacent district of St. Etienne). This aerolite differs greatly in appearance from all those that have been hitherto observed. It is black throughout its whole substance, and is composed of slightly adhering friable lamellæ; when rubbed on paper it leaves a grey trace not unlike that of plumbago: it acquires a kind of bituminous polish by friction, and by bruising in a mortar it is reduced to thin flat plates instead of powder. When heated it exhales a slightly bituminous odour. Its specific gravity is 1.94. Certain small granular portions of the stone were found to be attracted by the magnet. When calcined in contact with air its colour soon changed from black to red, without losing any weight; but when ignited in a small retort it remained black, gave out a little carbonic acid, and lost about 17 per cent. of its weight, which probably was water, which its porous structure enables it readily to absorb. By ebullition with muriatic acid it affords a very small quantity of sulphuretted hydrogen. It has been analysed by Vauquelin with the following result:

- 38. sub-oxide of iron
- 30. silex
- 14. magnesia
- 2. oxide of nickel
- 2. oxide of manganese
- 2. oxide of chrome
- 2.5 carbonaceous matter

90.5

9.5 sulphur, water, and loss

An analysis of the same substance has been published by Thenard, who found in it the same ingredients as those already mentioned, but in somewhat different proportions. Mr. Howard's analyses of the aerolites related above, were not calculated to detect the presence either of manganese or of chrome; as far therefore as certainly appears, the loose texture of this stone and the presence of a little carbonaceous matter are the principal circumstances in which it differs from the other meteoric stones. If at the period of its formation or explosion it had been subjected to a high degree of heat, the iron and other metals would have been deoxygenated at the expence of the carbon, and this would probably have also induced a greater compactness of structure, in which case

^a Journ. de Phys. 1803.

^b Ann. de Chim. lix. p. 34. 104.

the composition and probably the external characters would have been strictly analogous to those of the other aerolites.

11. On the 22d of May 1809,^a an aerolite, or rather several, fell at Stannern in Moravia. Of the circumstances attending its fall there is no published account; the following are the external characters of a specimen in the possession of the Count d'Unin, and procured by him on the spot. Its external surface is black, and shows evident signs of fusion. Internally it presents a pale ash-grey earthy base in which are disseminated some concretions of a darker colour, and more compact than the rest of the mass; a few dispersed grains of pyrites are also visible. The entire stone is tender, friable, and its specific gravity is 3.19. It is not attracted by the magnet, but before the blow-pipe it fuses with difficulty into a black glass, which is then acted on by the magnet. On digestion in muriatic acid it affords a very small quantity of sulphuretted hydrogen. It has been analysed by Klaproth, by M. Moser of Vienna, and by Vauquelin. The particulars of Klaproth's analysis we are unacquainted with, being only informed in general that the composition of this aerolite bears a strong resemblance to that of basalt. Vauquelin's analysis, which was performed with much care, gives the following constituent parts of the entire stone.

- 50. silex
- 12. lime
- 9. alumine
- 29. oxide of iron
- 1. oxide of manganese
- nickel and sulphur, of each a trace.

101.

Hence it appears that the Moravian aerolite is specifically different from all those that have hitherto been described, by the absence of magnesia, and the presence of lime and of alumine.

12. The last meteoric stone^b that we shall mention is one that fell near Sigena in Arragon, in the year 1773, and was deposited in the royal museum at Madrid. In 1805 M. Proust obtained leave to analyse a portion of it, and to publish the result, with a description of the stone. Its present weight is 6 lbs 10 oz. but several fragments have been broken from it: where the surface is unbroken it presents the black vitreous crust which is characteristic of most of these bodies. Its colour internally is a light bluish grey. It is an aggregate of

globular concretions the largest of which are scarcely bigger than hemp-seeds, and which on examination with a lens are evidently covered over with extremely minute crystalline points. Intermixed irregularly with these concretions are particles of bronze coloured pyrites and of metallic matter. On pulverizing portions of the stone, and separating by the magnet the metallic particles, their proportion to the rest of the mass was found to vary from 17 to 22 per cent. This metallic matter was an alloy of iron and nickel in the proportion of 97 of the former to about 3. of the latter. The rest of the stone, including the pyrites, was then analysed and afforded by the usual methods,

- 12. sub-sulphuret of iron
- 5. black oxide of ditto
- 66. sillex
- 20. magnesia

103.

The excess of weight in this as in the preceding cases is no doubt to be attributed to the oxidation of the iron.

AFFINITY.

M. Berthollet, one of the most profound and eminent chemical philosophers of the age, has endeavoured to shew that it is the tendency of chemical affinity to combine bodies in all proportions, so that where any limits to this indefinite combination appear, they arise from the operation of circumstances distinct from chemical affinity, which essentially modify its action.

On the other hand it is advanced by many most ingenious chemists, and supported by a daily encreasing body of experiments, that substances unite in proportions which are rendered definite by the sole operation of their mutual affinity, and are equally definite whether only one or more compounds of the same bodies exist.

To this opinion, which has been advanced by Richter, Proust, and other eminent chemists, Mr. Dalton^c has added a most important rule (supported by a variety of striking examples) which is, that where two bodies combine in different proportions, if the quantity of one of them be assumed as a fixed number, the proportions of the other body that unite to it are in the simplest possible ratio to each other, being produced by multiplying the lowest proportion by a simple integral number as 2, 3, 4, &c.

Thus for example, if a metal can combine

^a Ann. de Chim. lxx. 321.

^b Journ. de Phys. 1805.

^c New System of Chemical Philosophy.

chemically with different proportions of oxygen, if 100 of the metal take 9 of oxygen for the lowest degree of oxygenation, all the other degrees will be in the proportion of 100 of metal to twice 9 (18) of oxygen; or 100 of metal to three times 9 (27) of oxygen; or 100 of metal to four times 9 (36) of oxygen, &c. &c. A reason for this simplicity in the ratio of binary compounds may be found in the general principle assumed by Mr. Dalton, which is, that in all cases the simple elements of bodies are disposed to unite atom to atom singly, or if either is in excess it exceeds by a ratio to be expressed by some simple multiple of the number of its atoms.

Hence, from the relative weights of the constituent parts of a compound, Mr. Dalton infers the relative weights of the ultimate particle or *atom* of each of these parts; and, this being found, the number of atoms of each constituent which enters into the formation of the compound particle is also deduced.

Thus (taking a compound of two constituent parts A and B. as the simplest case) if its elements are found by experiment to unite in the proportion of 5 of A to 7 of B, it is inferred by Mr. Dalton that the numbers 5 and 7 express the comparative weight of an atom of A and B. respectively. And these elements, though uniting in several proportions, will yet be found by experiment to be confined to either 5 A to 14, 21, 28, &c. of B. which is, one atom of A to 2, 3, 4, &c. atoms of B; or conversely it will be 7 B to 10, 15, 20, &c. of A, which is one atom of B, to 2, 3, 4, &c. atoms of A. It is essential to the consistency of this system therefore, that there should be no other proportions of combination between these two elements, unless indeed it be one that is expressed by an even sub-division of one of these proportions, as for example, 5 A to 7, $10\frac{1}{2}$, 14, &c. of B; in which case the $10\frac{1}{2}$ being resolvable into three portions of $3\frac{1}{2}$ each, the number expressing the relative weight of an atom of B, must be reduced to $3\frac{1}{2}$ instead of 7, and consequently the several proportions of 7, $10\frac{1}{2}$, 14, and 21 of B, will be resolved respectively into 2, 3, 4, and 6 atoms of B.

To verify the numbers expressing the relative weights of an atom of A and B, (supposing that of A to be assumed as 5, and that of B as 7) let them each be examined in their separate compounds with a third body, C. Then, suppose that in the simplest binary compound of A and C, analysis discovers 3 parts by weight of C, to 5 of A, it is assumed, that, as 5 is

taken as the numerical expression of an atom of A, the number expressing an atom of C. must be 3; and *consequently*, if this mode of estimation be just, it will also be found by experiment that in the simplest combination of C with B, 7 parts of B will unite exactly with 3 parts of C. This supposes indeed that this simple combination of one atom of each body is known by experiment; but even if this should not be the case, the general principle will not be contravened, if, instead of a single portion of C being found, there should be a double, triple, or quadruple portion, provided the radical number or common divisor is 3, that of B being 7.

To illustrate this by an example from Mr. Dalton (in which however the numbers assumed are not perfectly accurate though sufficient for the present purpose.) The substance of which as far as we yet know the smallest relative weight enters into chemical combination is hydrogen, and on this account the weight of its atom is assumed as unity, and is the standard of comparison for the relative weight of the atom of all other bodies. The only compound of hydrogen and oxygen that we know is water, in which the oxygen is to the hydrogen as 7 to 1. The number 7 therefore is assumed as the relative weight of the atom of oxygen, and water is a binary compound containing an atom of hydrogen with an atom of oxygen in every atom of water. Sulphuretted hydrogen is composed according to Mr. Dalton of 13 parts by weight of sulphur and 1 of hydrogen. If it be assumed that an atom of sulphuretted hydrogen contains an atom of sulphur united to an atom of hydrogen, the relative weight of an atom of sulphur must be 13. To prove that this number 13 may be assumed as the weight of an atom of sulphur, let it be examined in its compounds with oxygen, and if correct, all the compounds of these two elements will contain for every 13 parts by weight of sulphur, either 7, or 14, or 21, &c. parts of oxygen, according as the compound contains to every atom of sulphur one, or two, or three atoms of oxygen.

Now according to Mr. Dalton, *Sulphureous acid* actually contains 13 parts by weight of sulphur to 14 of oxygen, and therefore its atom consists of one atom of sulphur to two atoms of oxygen; and *Sulphuric acid* consists of 13 parts by weight of sulphur to 21 of oxygen, or one atom of the former to three atoms of the latter.

This hypothesis therefore is perfectly consistent in the above examples.

The comparative *weight* of each atom being thus ascertained, the relative *diameter* of the atom is found by comparing its relative weight with the specific gravity of the substance of which the atom is an integrant particle. But as this part of Mr. Dalton's system is not essential to our present purpose we shall not pursue it.

Not only do elementary atoms unite in definite proportions but also compound particles unite in the same manner. Thus both sulphuric acid and potash are compound particles, being each oxyds, the one of sulphur and the other of potassium. But as potash combines with two different proportions of sulphuric acid, one being just double the quantity of the other, the compound, *sulphat of potash*, may with propriety be considered as composed of an *atom* of potash with an *atom* of sulphuric acid, and the compound, *super-sulphat of potash*, may be considered as consisting of one atom of potash to two atoms of sulphuric acid.

Mr. Dalton gives the term *Binary atom* to any compound of two elements in which one atom of each is combined, and hence there can be but one species of binary compound of any two elements.

A *Ternary Atom* is composed of two atoms of one of the elements with one atom of the other, and hence there may be two species of ternary atoms of the same element, according as one or other is in the greater proportion. Thus an atom of nitrous oxyd is a ternary compound of two atoms of azote and one atom of oxygen; and on the other hand nitrous acid is also a ternary compound of the same elements, but consisting of one atom of azote with two atoms of oxygen.

A *Quaternary Atom* is composed of three atoms of one element with one atom of the other, and hence also there may be two species of quaternary atoms as either element predominates; and so on of the other numbers.

We shall now proceed to mention a number of facts that illustrate in a striking manner the chemical union of substances in *definite proportions*.

If one measure of pure oxygen and two measures of hydrogen be mixed in a jar over mercury and ignited by the electric spark, both the gasses will disappear, and water will be produced. If two measures of each gas be used, water will be produced as before, but one measure of oxygen will remain. Hydrogen there-

fore unites with water in one exact proportion, and in no other.

If a piece of well burnt charcoal be confined in oxygen gas and inflamed by a burning glass the volume of gas is not altered when again cooled, but the whole is converted into carbonic acid gas. If more oxygen be present than is necessary for the consumption of the charcoal, the products will be carbonic acid gas and an excess of oxygen; if there is less oxygen than will consume the charcoal, carbonic acid alone will be produced, and part of the charcoal will remain unconsumed.

The combination of two elements in several definite proportions is very happily shewn by the various compounds of oxygen and azote. These are nitrous oxyd, nitrous gas, and nitrous acid gas.

If two measures of *Nitrous Oxyd*, and two measures of hydrogen are ignited by the electric spark, the product is water, and two measures of azote remain. Now as water is produced by two measures of hydrogen and one of oxygen the nitrous oxyd here employed must have consisted of two measures of azote with one of oxygen condensed into the space of one measure.

If charcoal is ignited in two measures of *Nitrous gas* the products are one measure of carbonic acid gas and one measure of azote. Hence, as carbonic acid gas always occupies the same volume as the oxygen of which it is formed, nitrous gas consists of equal volumes of oxygen and of azote not condensed by their union.

If two measures of nitrous gas be mixed over water with one measure of oxygen gas, both of them totally disappear, and a solution of *Nitrous acid gas* in water is the result.

In all the above examples the proportions of azote and oxygen encrease or diminish by equal quantities, and no intermediate states of combination are known.

Dr. Wollaston has given some striking experiments in illustration of this theory of definite proportions in the composition of some super-acid and sub-acid salts,* which may be here mentioned as they are easily performed. Let two grains of crystallized carbonat of potash recently prepared be wrapped in thin paper, and passed up into an inverted tube filled with mercury, and let the gas be extricated from it by muriatic acid, and the space it occupies be marked on the tube. Then let four grains of the same carbonat be exposed for a short time to

* Phil. Trans. for 1808.

a red-heat, and afterwards let the gas be expelled from it in the same apparatus, and it will be found to occupy exactly the same space as that obtained from the two grains of crystallized salt in the former experiment.

The same results are obtained from the super-carbonat and the sub-carbonat of soda.

Super-sulphat of potash in like manner contains twice the quantity of acid as the neutral sulphat. Let twenty grains of carbonat of potash be mixed with about twenty-five grains of sulphuric acid in a covered platina crucible, or in a glass tube, and this mixture gradually heated till it ceases to boil and becomes slightly red-hot. This will produce the super-sulphat of potash, which will be very nearly neutralized by an addition of 20 grains of the same carbonat of potash.

The common super-oxalat of potash is shewn by Dr. Thomson to consist of potash united to twice the quantity of oxalic acid necessary to saturate it. If two equal portions of this super-oxalat be taken, and one portion calcined so as to destroy the acid, the alkali that remains will be just sufficient to saturate the other portion.

When nitric or muriatic acid is added to the common super-oxalat of potash, the latter salt is only partially decomposed, and crystals form in the mixture which are found on examination to be a *Quadroxalat of Potash*, or potash with *four* times as much acid as will saturate it.

The formation of these various salts with a definite excess of acid which is expressed by a simple multiple of the least definite quantity is particularly important as it affords an answer to the powerful objection urged by M. Berthollet against the common opinion of chemical affinity. This eminent chemist shews that a considerable excess of a weaker acid will decompose a compound of a base and a stronger acid; for example, that a large quantity of nitric acid added to sulphat of potash will occasion some crystals of nitre to form, though the nitric acid has a weaker affinity to potash than the sulphuric. But though there is an undoubted decomposition of some portion of the sulphat of

potash in this case, it is highly probable that for every particle of nitre formed there is an equivalent quantity of a super-sulphat of potash produced, in equally definite proportions with the neutral sulphat, and in which probably the acid is in the ratio of a simple multiple of that which exists in the neutral salt.

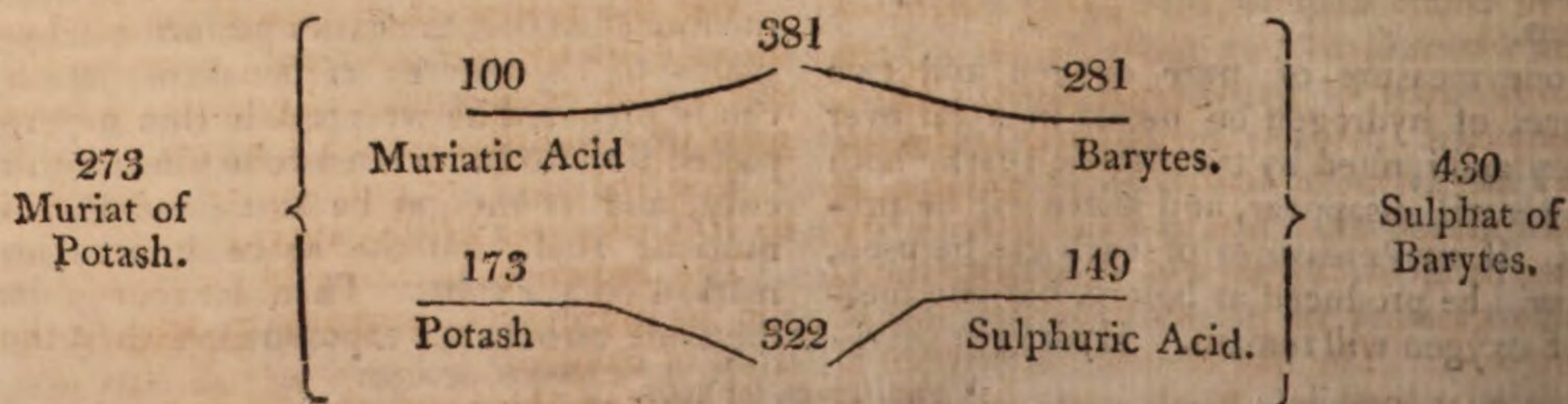
Among the philosophers who within these last few years have laboured with the greatest zeal and success in discovering the laws of chemical affinity a distinguished place is due to Professor Berzelius,^c whose experiments we shall now briefly notice. He states that he was led to this train of enquiry from the two following most important theorems laid down by the learned Richter.

1. When two bodies A. and B. have each an affinity for two others C. and D. the C. which saturates a given quantity of A. is to the D. which saturates the same quantity of A. in the same proportion as the C. saturating any given quantity of B. is to the D. saturating the same quantity of B. Hence the saturating proportions of A. C. A. D. and B. C. being known those of B. D. may be found by simple calculation. For example, let A. B. C. and D. be respectively sulphuric acid, muriatic acid, barytes and potash, and let 100 parts of sulphuric acid be saturated by 190 of barytes, and by 116 of potash, and let 100 of muriatic acid be saturated by 281 of barytes, then, the quantity of potash saturating 100 of muriatic acid will be 173;

Bar. Pot. Bar. Pot.

for 190 : 116 :: 281 : 173 nearly.

This law of chemical combination is indeed a direct inference from the fact that when two neutral salts are mixed together and decompose each other the mixture remains neutral. Thus, supposing 381 parts of muriat of barytes be exactly decomposed by 322 parts of sulphat of potash, and the mixture remain neutral, the respective proportions of the new compounds formed will be 273 of muriat of potash, and 430 of sulphat of barytes, as by the following scheme:



^c An. Chim. Tom. 77 to 83 inclusive.

The *respective* proportions of potash and barytes that saturate any acid are always as 173:281, and in the decomposition here assumed the muriatic acid that saturates these bases is 100 parts. Therefore the sulphuric acid must be 149 parts as calculated both from the elements of sulphat of potash and sulphat of barytes. In the former case 116 of potash saturate 100 parts of sulphuric acid, and $116 : 100 :: 173 : 149$. In the latter case 190 of barytes saturate 100 of sulphuric acid, and $190 : 100 :: 281 : 149$.

The importance of this law of chemical combination is so great that the composition of all the binary compounds might be found with absolute certainty, provided the data founded on actual experiment could be brought to perfect accuracy. Hitherto however this has not been the case, as no series of numbers representing the neutral compounds has yet been given which will apply throughout. It is a chief part of the present labours of Prof. Berzelius to correct the elements of these calculations by varied experiments conducted with great care and intelligence.

Another equally important law laid down by Richter is, that when the metal of a neutral metallic solution is precipitated by another metal, it is the metallic base alone which is changed, the oxygen and the acid remaining united with the last added metal. Hence it follows that all the different metallic oxyds which saturate a definite portion of acid contain the same quantity of oxygen. Or in other words it may be expressed that a given quantity of any acid combines to saturation with only a definite proportion of oxygen united to so much of any base as contains this portion of oxygen. Thus for example, if 100 parts of sulphuric acid saturate 20 parts of oxygen and the base united with it, the proportion of every oxyd that combines with 100 of sulphuric acid, and the composition of every neutral sulphat is known as soon as the oxyd itself is analyzed. And, conversely, the composition of any unknown oxyd may be discovered by finding the quantity of this oxyd which neutralizes a given weight of any acid whose saturating quantity of oxygen in any other oxyd is previously known. Thus, for example, if 100 parts of sulphuric acid saturate any oxyd that contains 20. of oxygen, it may be inferred that 116 parts of potash are composed of 20 of oxygen and 96 of potassium, since this quantity of potash saturates 100 of sulphuric acid. The like quantity of oxygen is therefore contained in 78 of soda, in 190 of

barytes, &c. &c. each of which saturate 100 of sulphuric acid.

The late discovery of the compound nature of the alkalies and earths therefore gives an additional importance to this law of chemical affinity.

Another law of chemical combination which is laid down by Berzelius, and illustrated by numerous examples, is the following, viz. In any compound of two oxydated substances, that substance which is attracted to the positive pole of the electric circuit (the acid, for example) contains as much oxygen as is produced by multiplying the oxygen of the substance attracted to the negative pole (such as alkali, earth, metallic oxyd) by some of the integral numbers 2, 3, 4, 5, &c. For example, as 100 parts of sulphuric acid saturate as much of any oxyd as contains about 20 parts of oxygen, the quantity of oxygen in 100 parts of the acid itself must be equal to twice 20, or three times 20, &c. In this example it will be shewn presently that sulphuric acid contains almost exactly three times 20, or 60, per cent. of oxygen. Most of the other acids however contain only twice the oxygen of their saturating base: the carbonic and sulphureous acids are of this kind.

In all the compounds in which water forms an element (which are all the crystallized salts and liquid acids) this substance also seems to be subjected to some similar law of definite proportion, as will be soon explained.

We shall now give a short abstract of a few of the important series of Prof. Berzelius' experiments, to shew to what degree they illustrate and confirm the above laws of chemical combination, together with some others which will be stated in their place.

The composition of sulphuric acid which has so often been attempted was ascertained in several methods; and first through the medium of the oxyd and sulphuret of lead.

Lead and Oxygen. Lead has three degrees of oxygenation, viz. the yellow, the red, and the brown.

For the yellow oxyd, some pure lead (reduced from the nitrat of lead) was dissolved in nitric acid evaporated and ignited; a hundred parts of metal thus gained 7.8 of oxygen.

The red oxyd, or purified minium, contains to 100. of metal 11.07 oxygen.

The brown oxyd formed by digesting minium in nitric acid, contains to 100. of metal 15.6 of oxygen.

Therefore these portions of oxygen, viz. 7.8;

11.07; and 15.6, are respectively in the proportions of 1, $1\frac{1}{2}$ and 2.

The yellow oxyd is the only one which enters into the salts of lead.

Lead and Sulphur. 100 parts of lead mixed with as much pure sulphur, and heated in a close vessel, as long as any sulphur was sublimed, produced 115.6 of the sulphuret; so that 100 parts of lead when thus united with sulphur absorb 15.6, which is exactly twice the weight of oxygen united with the same quantity of lead in the yellow oxyd. On this coincidence a law of combination is deduced which will be presently mentioned.

This sulphuret of lead is therefore thus composed:

		Oxygen.	
Lead	- 86.51	with 6.748	produce 93.258 oxyd of lead
Sulphur	13.49	— 19.752	— 33.242 sulphuric acid
Sulphuret of lead	100.00	26.500	126.5 sulphat of lead

Two things are to be particularly noticed here:

One of them is: that the sulphur of the sulphuret of lead was exactly sufficient when converted to sulphuric acid to saturate the lead of the same sulphuret when converted to the suboxyd of lead.

The other thing to be noticed is: that the quantity of the sulphur in the sulphuret was almost exactly double the quantity of oxygen taken up by the lead of the sulphuret, being as 13.49 to 6.748.

From the former of these facts the author infers as a general rule, that a metal combines with sulphur in such a proportion, that when the sulphur is converted to sulphuric acid and the metal to an oxyd, the sole product will be a neutral sulphated oxyd of the same metal.

From the latter of these two facts the author infers: that in every neutral sulphat the oxygen of the base equals half the weight of the sulphur of the acid with which it is saturated.

The composition of sulphuric acid is inferred from the above oxydation of sulphuret of lead, to be in the proportion of 13.49 of sulphur to 19.752 of oxygen, the whole addition of oxygen to the sulphuret being 26.5, and 6.748 of this being estimated as the portion belonging to the oxyd of lead.

Sulphuric acid therefore consists of

Sulphur	40.58	—	100.000
Oxygen	59.42	—	146.426
	100.00		246.426

Lead	. 100	86.51
Sulphur	15.6	13.49
	115.6	100.00

A hundred parts of the sulphuret of lead last described were digested in nitro-muriatic acid till the whole was converted into sulphat of lead, the sulphur and lead both acquiring oxygen from the nitro-muriatic acid. No product whatever was yielded from the sulphuret but the sulphat of lead, which was perfectly neutral and weighed 126.5 parts. The respective changes that took place therefore, supposing the base of this salt to be the yellow oxyd, are as follows:

According to the second of the two propositions just mentioned, 100 parts of sulphuric acid therefore will saturate so much of any oxydated base as contains $\frac{40.58}{2} = 20.29$ of oxygen.

As an exact determination of the elements of sulphuric acid is of great importance in analysis, the author proceeds to compare the above mentioned result with those produced by other modes of operating.

Both Bucholz and Klaproth have sought to fix the elements of this acid by acidifying a given quantity of sulphur, and then combining it with the barytes of a known quantity of some soluble barytic salt. The analysis of sulphat of barytes depends also on that of carbonat of barytes, out of which all the barytic salts are prepared. By multiplied experiments the author fixes the elements of carbonat of barytes at

Carbonic acid	21.6	—	100
Barytes	78.4	—	363
	100.0		463

Of this carbonat, 100 parts (containing 78.4 of base) gave from 118.6 to 119 parts of sulphat of barytes, which will give for the elements of sulphat of barytes within $\frac{1}{10000}$ of the following numbers:

Sulphuric acid	34	—	100
Barytes	66	—	194
	100		294

Bucholz acidified 100 parts of fused sulphur with nitro-muriatic acid, and by combining with barytes the sulphuric acid thus produced obtained 724 parts of sulphat of barytes. If this sulphat is estimated according to Berzelius' result above given, its acid part will be 246.16, whence 100 parts of sulphur will have combined with 146.16 of oxygen, and this estimation of sulphuric acid will be found to correspond almost exactly with that already given as found by the acidification of sulphuret of lead.

Sulphureous Acid. The production of this acid by the direct combustion of sulphur being attended with nearly insuperable difficulties, Pr. Berzelius attempted its analysis by means of the sulphite of ammonia. This salt was decomposed by muriat of barytes, and the resulting sulphite of barytes was changed to the sulphat of barytes, by means of nitric acid, none of the sulphureous acid being expelled in the process. By these and other experiments the author determines the elements of sulphureous acid to be

Sulphur	50.57	—	100.00
Oxygen	49.43	—	97.83
	100.00		197.83

The oxygen in the sulphureous acid is therefore to that in the sulphuric acid very nearly as $1:1\frac{1}{2}$; as 100 parts of sulphur unite with 97.83 of oxygen in the sulphureous, and with 146.426 in the sulphuric, and $97.83 \times 1\frac{1}{2} = 146.785$.

Copper with Sulphur and Oxygen.

The author proceeds to examine the com-

Copper	100.0	with 12.800 oxygen give	112.800 suboxyd of copper
Sulphur	25.6		37.485 sulphuric acid
Sulphuret of Copper	125.6		50.285
			175.885 Sulphated Suboxyd of Copper

This therefore would give for the composition of the suboxyd of copper,

Copper	100.0	—	88.652
Oxygen	12.8	—	11.348
	112.8		100.000

And the sulphated suboxyd of copper would consist of 63.085 acid to 112.8 of suboxyd: or as follows: (the oxygen of the base equalling half the sulphur in the acid).

Sulphuric acid	100.0	—	35.87
Suboxyd of copper	178.8	—	64.13
	278.8		100.00

pounds of copper with sulphur and oxygen, to ascertain whether they agree with those of lead in the three laws of combination which he had laid down. These laws (to repeat them) are the following:

1. That the sulphuret of any metal, when oxydated, is totally changed to a neutral sulphat.

2. That in every sulphat the oxygen belonging to the base equals half the weight of the sulphur in the acid.

3. That in every compound of an acid and a base, the oxygen of the acid equals that of the base multiplied by some integral number. To this may be added the other law of all chemical combination (which is entirely adopted by the author) namely,

4. That where two bodies unite in different proportions, if the quantity of one of them be assumed as a fixed number, the proportions of the other body are in the simplest ratio to each other, being produced by multiplying the lowest proportion by some integral number.

Copper and Sulphur. One hundred parts of copper heated in a retort with as much sulphur, till all the excess of the latter was expelled, produced 125.6 of sulphuret of copper. Some difficulties attend this operation to produce uniform results, but the above number appears to approach the nearest to accuracy. Hence from this single fact, the following composition of the suboxyd and sulphated suboxyd of copper should be made out, assuming that the oxyd of copper corresponding with this sulphuret is at a minimum of oxydation.

Now, supposing the *Peroxyd* of copper to contain twice the quantity of oxygen to a given weight of metal, as the suboxyd, this peroxyd of copper would consist of

Copper	100.0	—	79.618
Oxygen	25.6	—	20.382
	125.6		100.000

Then if this peroxyd were the base of a neutral sulphat of copper, this sulphated peroxyd would contain

Sulphuric acid	100.000	—	50.113
Peroxyd of Copper	99.548	—	49.887
	199.548		100.000

since 99.548 would be the quantity of this peroxyd that contains oxygen equal to half the sulphur in the acid.

Lastly, if this latter sulphat were formed by

the direct oxygenation of a super-sulphuret of copper, this would of course contain a double proportion of sulphur, and its proportions when resolved would be as follows :

Copper	-	100.0	Oxygen.	with 25.60	give 125.60 peroxyd of copper
Sulphur	-	51.2		74.97	126.17 sulphuric acid
Super-sulphuret		151.2		100.57	251.77 Sulphated Peroxyd of Copper

The author then proceeds to examine the accuracy of these hypothetical numbers by actual experiment. We shall state them in a very few words.

The peroxyd of copper was formed by evaporating and igniting a given weight of metal dissolved in nitric acid. Another portion of the nitrat was decomposed by a carbonated alkali, and the precipitate ignited. In the former case some of the metal was volatilized with the acid, and in the latter a portion was left in the solution and separated by sulphuretted hydrogen, both of which circumstances produce some little inaccuracy in the results. An allowance must also be made for the sulphur and carbon retained by all copper. If this be fixed at $\frac{1}{2}$ per cent. (which however is quite arbitrary) the composition of the peroxyd of copper will be

Copper	80	—	100
Oxygen	20	—	25
	100		125

which very nearly agrees with the proportion deduced from the sulphuret.

The suboxyd of copper was formed by mixing 10 parts of the peroxyd with the same quantity of pure copper in a flask, containing 75 parts of muriatic acid, and keeping the vessel well closed on a gentle stove-heat for three days, with frequent shaking. After this the whole of the peroxyd and part of the copper were dissolved, and the quantity of the latter was found by weighing the undissolved portion. Then supposing the oxygen of the peroxyd to be equally divided between its own portion of metal and that added, and the whole to constitute the suboxyd, this will nearly contain half the oxygen of that in the peroxyd, allowing a small deviation to be produced by the unavoidable action of the muriatic acid on a small portion of the copper, independently of the oxygen present, which was shewn by an escape of hydrogen when the vessel was opened. A suboxyd of copper containing half the oxygen of the peroxyd, will therefore consist of

Copper	88.89	—	100.0
Oxygen	11.11	—	12.5
	100.00		112.5

This very nearly agrees with the result of a similar experiment made by Mr. Chenevix, who reckons 13. of oxygen to 100. of metal; and the composition of this suboxyd estimated from the sulphuret is the mean of these two, or 12.8 of oxygen.

The common sulphat of copper was then analyzed: 5 parts of this salt dried at a tin-melting heat and decomposed by muriat of barytes, gave 7.22 of sulphat of barytes, the acid of which is 2.455, leaving therefore 2.545 for the oxyd of copper in the 5 parts. The basis of this salt is the *peroxyd* of copper, and therefore this salt is properly the sulphated peroxyd of copper. It is thus composed, from the above analysis :

Sulphuric acid	49.10	100.00
Peroxyd of copper	50.90	103.66
	100.00	203.66

On the other hand, if 100 parts of sulphuric acid neutralize so much of any base as contains 20.29 parts of oxygen, it would require 101.45 instead of 103.66 of the peroxyd.

The quantity of peroxyd saturating 100. of sulphuric acid, as estimated by the composition of the sulphuret, is 99.548, which is still sufficiently near 103.66 to come within the limits of probable error.

The above experiments on the compounds of copper with sulphur and oxygen are so far defective that they do not exhibit any super-sulphuret of copper, which is the regular base of the common sulphat of copper or sulphated peroxyd: nor on the other hand do they shew any sulphated suboxyd of copper, which is the regular product of the oxydation of the subsulphuret actually known. They sufficiently illustrate, however, the law of definite proportions in the different degrees of oxydation; and that

of a precise portion of oxygen in the oxyd saturated by a given quantity of sulphuric acid.

Iron, Sulphur and Oxygen.

We shall briefly mention these, on account of an apparent anomaly in the relation between the sulphuret and sulphat as already laid down.

Subsulphuret of Iron. This was formed by heating red-hot for a considerable time a mixture of thin iron plate and thrice its weight of sulphur, till all the excess of the latter was sublimed. The remaining sulphuret of iron was brilliant, brittle, and magnetic only in powder. A given portion of it was analyzed by being first totally dissolved and acidified in nitro-muriatic acid, and the sulphuric acid thus generated was separated by muriat of barytes and the oxyd of iron by ammonia. Reckoning 34 per cent. of acid, or 13.797 of sulphur, in sulphat of barytes, and 69.3 per cent. of iron in the peroxyd here produced by the action of the nitro-muriatic acid, this subsulphuret of iron would consist nearly of

Sulphur . . .	37	—	58.75
Metallic iron	63	—	100.00
	100		158.75

The super-sulphuret of iron, or natural crystallized pyrites, gave by a similar analysis,

Sulphur . . .	53.92	—	117
Iron . . .	46.08	—	100
	100.00		217

Therefore the sulphur combined with 100 parts of iron is twice as much in the super-sulphuret as in the subsulphuret.

Oxyds of Iron. This very important subject has been examined here with peculiar care. It was first asserted by Proust, and has been pretty generally allowed, that there are but two oxyds of iron, the black and the red oxyd, the former being the suboxyd and the latter the peroxyd. That there are these two distinct oxyds is not doubted, but Thenard has given some experiments which appear to establish

another oxyd of a still lower degree of oxygenation than the black oxyd, and which when first separated from its solution is *white*. If this be correct, there are three oxyds, namely, the white, the black, and the red, of which the latter has the highest proportion of oxygen. The existence of this white oxyd is also probable on account of the ratio of oxygenation, as will be further mentioned here, and also in the article *Iron* in this Appendix.

At present however only the black and the red oxyd are concerned, which may be here termed the Suboxyd and the Peroxyd.

The composition of these as determined by Berzelius from many experiments, is the following.

For the suboxyd

Iron . . .	77.22	—	100.0
Oxygen	22.78		29.5
	100.00		129.5

For the peroxyd

Iron . . .	69.34	—	100.00
Oxygen	30.66		44.25
	100.00		144.25

Therefore the oxygen of the peroxyd is to that of the suboxyd only as $1\frac{1}{2}$. to 1. for $29.5 \times 1\frac{1}{2} = 44.25$.

But on the other hand the sulphur of the super-sulphuret is twice the proportion of that in the sub-sulphuret: and therefore if each of these sulphurets were acidified and converted into a sulphat of iron (the base of the sulphat corresponding with the sub-sulphuret being the suboxyd, and that of the other sulphat being the peroxyd) it is evident that the laws that regulate this change as deduced from the sulphuret and sulphat of lead could not be preserved.

The combinations that would take place are as follows.

The sub-sulphuret converted into a sulphated suboxyd would give

Iron . . .	100.00	with	Oxygen.	29.50	give	129.5	Suboxyd
Sulphur . . .	58.75	—		86.03	—	144.78	Sulphuric acid
	158.75			115.53		274.28	Sulphated Suboxyd

In this case all the laws of combination are observed pretty accurately, the sulphuric acid saturating so much of the base as contains oxygen equal to half the sulphur in the acid,

within a trifling difference. But on the other hand, if the supersulphuret of iron or the natural crystallized pyrites (which contains a double proportion of sulphur) were totally

oxydated in the same way, and converted into a sulphat with the peroxyd for its base, it is obvious that the same relative proportions between the sulphat and the sulphuret could not be preserved, as the peroxyd is an oxygenation

of only $1\frac{1}{2}$ the quantity of the suboxyd, whereas the supersulphuret is a sulphuration of twice the quantity in the subsulphuret. This compound therefore, if it could exist, must be one with a double portion of acid as follows:

Iron	.	.	100.00	with	Oxygen. 42.25	.	give	144.25	Peroxyd
Sulphur	.	.	117.50	—	172.06	.	—	289.56	Sulphuric acid
Supersulphuret			217.50		214.31			433.81	Supersulphat

The resulting salt in this case therefore must be with excess of acid, for 289.56 : 144.25 :: 100 : 49.82 so that 100. of sulphuric acid would only unite with 49.82 of the peroxyd of iron which contains only 15.27 of oxygen; whereas it is found by all the previous experiments that 100. of sulphuric acid requires for its saturation

as much of any oxyd as contains 20.29 of oxygen, or thereabouts.

But the actual composition of the sulphated peroxyd of iron (or *red sulphat*) is very different. Berzelius finds it by experiment to contain about 100 sulphuric acid to 65.5 peroxyd, which are resolved into the following numbers.

Sulphuric acid	100	contain	Oxygen. 59.42	with	40.58	Sulphur
Peroxyd	.	.	65.5	—	20.10	— 45.40 Iron

* These numbers agree sufficiently well with the laws of combination all along observed, for the oxygen of the peroxyd is very nearly half the weight of the sulphur in the acid, and 100 parts of the acid saturate as much peroxyd as contains 20.1 of oxygen. Therefore the sulphuret of iron, which is the base of this sulphat, is one in which the sulphur is to the iron as 40.58 : 45.40 and would therefore consist of

Iron	100.
Sulphur	89.38
	189.38

which is an intermediate degree of sulphuration between the two actually ascertained by experiment. A sulphuret not far deviating from these proportions has been actually produced by Mr. Hatchett by distilling the magnetical pyrites with sulphur in a low red heat, as mentioned in our original article IRON.^a

Muriatic Acid.

A perfect analysis of muriat of silver that could be depended on even to a thousandth part is a great desideratum, as it would afford a means of ascertaining the muriatic acid in all the other muriats, and also the quantity of oxygen contained in the base of all these salts, if the hypothesis of equal saturation of acids by so much of every oxyd as contains a given portion of oxygen be correct. There is no great difficulty in ascertaining the quantity of metallic silver in a given portion of the fused muriat of silver, but it is not so easy to find the

exact proportion of oxygen that unites to the metal and of muriatic acid. It is thus attempted by Professor Berzelius.

Muriat of Silver. 100 of ignited carbonat of barytes contain by experiment 21.6 of carbonic acid, and therefore 78.4 of barytes, which last when saturated with muriatic acid gives 105.6 of muriat of barytes, which salt therefore contains 78.4 of barytes, and 27.2 of acid. Hence the elements of muriat of barytes are

Muriatic acid	25.75	100.0
Barytes	.	74.25
	100.00	388.4

On the other hand 105.6 of muriat of barytes decomposed by nitrat of silver produce 145.5 of fused muriat of silver, which last therefore contains all the acid in 105.6 muriat of barytes, namely, 27.2 parts, and 144.5 : 272 :: 100 : 18.7. Therefore 100. parts of muriat of silver contain 18.7 acid and 81.3 oxyd of silver.

Likewise, 100 parts of silver being dissolved in nitric acid, muriatic acid added in excess, and the whole evaporated and fused gave 132.7 of muriat of silver, the metal of which therefore is 100. parts, or (reduced to the proportion of 100 parts of the muriat of silver) this will contain 75.358 per cent. of silver, and 24.642 oxygen and muriatic acid.

But as muriat of silver has already been shewn to contain 18.7 per cent. of muriatic acid, the difference between 24.644 and 18.7, or 5.942, is the oxygen.

^a See Chem. Dict. vol. I.

From these data therefore the fused muriat of silver is thus composed :

Muriatic acid	18.7	100.000
Silver	75.358 } 81.3	Silver 402.984 }
Oxygen	5.942 }	Oxygen 31.775 }
	100.0	434.759
		534.759

And the oxyd of silver will consist of

silver	92.67	100.000
oxygen	7.33	7.925
	100.00	107.925

Therefore 100 parts of muriatic acid saturate so much of this base as contains 31.775 of oxygen, and if the rule of equal saturation be just, every base that saturates 100. parts of dry muriatic acid will contain 31.775 of oxygen, provided this analysis of muriat of silver be correct.

Another mode of analysing muriat of silver is by means of the sulphuret. Sulphuret of silver the author finds to consist of 100 silver to 14.9 sulphur; sulphuret of lead contains 100 lead and 15.42 sulphur; and suboxyd of lead contains 100 of lead to 7.7 oxygen. Then, applying Richter's rule, the sulphur saturating 100 parts of lead, is to the oxygen saturating 100 of lead, in the same proportion as the sulphur saturating 100 of silver is to the oxygen saturating 100 of silver. This will give 7.44 for the oxygen saturating 100 of silver; for 15.42 : 7.7 :: 14.9 : 7.44. If this result be taken in conjunction with the fact that 100. of silver produce 132.7 of the muriat of silver, this 132.7 of muriat will consist of 100. of silver, and 7.44 of oxygen, leaving 25.26 for the muriatic acid. This would give as much as 19.035 per cent. of muriatic acid in muriat of silver, and only 6.925 per cent. of oxygen in the oxyd of silver; and would give only 29.455 for the oxygen in the base saturated by 100. of dry muriatic acid.

As the latter mode of estimating muriat of silver is obviously exposed to many more sources of inaccuracy, the former is preferable. All things considered, the disagreement between the two is not very great, though sufficient to render it unsafe to take the mean number as the most accurate. We may therefore for the present infer that a dry saturated muriat (retaining the old theory of muriatic acid) contains for every 100 parts of muriatic acid about 31.5 of oxygen in the base which saturates the acid.

The author examines the muriats of copper

and lead with this view. The particulars we shall not here give, but the results considerably confirm this general law of equal saturation above mentioned.

On Water of Crystallization and Water of Composition.

Water according to Berzelius performs the part of a base when united to an acid, and of an acid when in union with a base. Some acids cannot exist in a separate state unless combined with a certain portion of water, which portion is exactly sufficient to oxydate that quantity of any metal which will combine with the acid to form a neutral compound. This is the case most remarkably with the muriatic acid, and also with the sulphuric, which last can never be concentrated singly to a greater degree than that at which it retains as much water as contains oxygen equal to half the sulphur in the acid itself, this being the proportion required in the bases saturating this acid as has been already fully described. Hence the impossibility of forming sulphuric acid by the combustion of sulphur in dry oxygen without the presence of water; and hence when the dry sulphats, such as alum, are distilled *per se*, the product is not sulphuric acid, but only its elements sulphureous acid and oxygen. The same takes place with the nitric acid, which can never be produced by the mere distillation of the dry nitrats that contain no water of crystallization, as these when heated yield only oxygen and nitrous acid gas till water be added.

Besides this *water of composition* there exists (often in the same compounds) another portion, which is the *water of crystallization*, and there seems some reason to infer from the author's numerous experiments, that the quantity of water of crystallization is such that its oxygen is always a multiplication or a division of

that of the base by an integrant number. Some of the experiments we shall mention.

Tartaric Acid, 100 parts of this acid well dried, were dissolved in water, and decomposed by acetited lead. The resulting tartrite of lead weighed 235.1. Five parts of this tartrite were then decomposed by sulphuric acid, and gave 4.23 of sulphat of lead, the composition of which being already known, that of tartrite of lead was inferred to be 164.87 oxyd of lead (containing 11.79 oxygen) to 100 of pure tartaric acid. Hence the 235.1 of tartrite of lead before mentioned contained 88.75 of tartaric acid free from water, and 11.25 of water; or, (in the same proportions) 100. parts of pure tartaric acid combine with 12.7 of water, containing 11.2 of oxygen. As this 11.2 does not very much differ from 11.79, it may therefore be inferred (making allowance for inaccuracy of experiment) that the water and the oxyd of lead saturating 100 parts of pure tartaric acid contain the same quantity of oxygen.

Citric Acid. 100 parts of dry citric acid were dissolved in water, mixed with 500. of oxyd of lead, evaporated to dryness and dried for some hours at a heat above boiling water. The residue weighed 379. parts, and hence there was a loss of water from the acid amounting to 20.85 per cent. Another 100. parts of the same citric acid combined with lead from the acetite, as in the foregoing experiments with tartaric acid, gave 237.56 of citrat of lead. Another 100. of the same citric acid heated on a sand bath till it first melted and then hardened,

but without decomposition, lost 7.08 of water. 100. parts of the citrat of lead treated with sulphuric acid, gave 90.56 of sulphat of lead, which contain 66.66 of oxyd of lead, and hence the composition of citrat of lead is 1. of acid to 2. of oxyd of lead. From these data the inferences (which need not be gone over at length) are, that 100 parts of mere citric acid saturate as much oxyd of lead as contains 14.13 oxygen: that 100 parts of the crystallized acid contain 20.85 of water, 7.08 of which may be repelled by heat alone, and may therefore be considered as *water of crystallization*; and the remaining 13.77 is the *water of composition*, and the former is (within a trifling difference) half the latter. Moreover, 100. of real citric acid will unite to 17.14 of water of composition (which here acts the part of a base, as it is expelled only by displacing it by the intervention of another base) and this 17.14 of water contains 15 of oxygen; and this quantity of acid also combines with 8.52 water which contains half this quantity of oxygen. Hence (making large allowance for inaccuracy) the oxygen of the water of crystallization in citric acid being taken as 1. that of water of composition, and also that of the saturating portion of oxyd of lead are each about 2. which agrees with the law of composition laid down.

Many other saline substances examined by the author were found tolerably well to agree with the above law. For example, 100 parts of crystallized sulphat of iron contain the following elements, viz.

Sulphuric acid	—	—	28.9	containing	17.34	oxygen
Suboxyd of iron	—	—	25.7	—	5.8	
Water	—	—	45.4	—	40.16	

therefore the oxygen of each of these three elements is respectively in the proportion of 1.3 and 7.

The author gives many other experiments on this subject from which he deduces the following law, namely, that in every compound of three or more oxydated substances, the oxygen of that constituent part which contains the least quantity of it is a common divisor for the other quantities of oxygen. And where one of the compounds is *water* its oxygen is equal to that of the base multiplied by some integral number. But it does not always happen that the oxygen in the water bears the same simple ratio to that of the acid; though each of them are measured by a simple multiplication of that of the lowest base. Thus in the case just stated, the oxygen

of the water is to that of the base as 7 to 1, and that of the base is to that of the acid as 1 to 3; but that of the water is to that of the acid as 7 to 3, which is a ratio that cannot be expressed by an integral number.

ALALITE. See AUGITE.

ALAUNSTEIN.

A specimen of this mineral was found by Klaproth^a to contain

55.5	sillex
19.	alumine
16.5	sulphuric acid
4.	potash
3.	water
98.0	

^a Journ. de Phys. lxxi. 412.

From the concurrence of this analysis with that of Vauquelin, it may be concluded that the above are the ingredients which enter into the composition of the alum-stone of La Tolfa. The difference in the respective proportions obtained by these able chemists depends in part, no doubt, on a want of perfect uniformity in different portions of the mineral itself.

ALBUMEN.

Dr. Bostock has given some useful observations concerning this substance.^a When white of egg is coagulated by heat and then long digested in water, about a fourth part is dissolved, the remainder being untouched. White of egg also loses about 80 per cent. of its weight by gentle drying, which loss appears to be pure water. When water containing only a thousandth part of pure albumen is heated to boiling its presence is indicated by a perceptible opacity. The *pure* albumen here mentioned is reckoned to constitute $15\frac{1}{2}$ per cent. of the entire white of egg. A solution of albumen of the above strength is rendered milky by a few drops of corrosive sublimate solution, and after a while a curdy precipitate collects. Nitromuriat of tin has a similar effect but is not quite so powerful. Equal parts of an infusion of galls (half an ounce to half a pint of water) and a solution of $\frac{1}{1000}$ of pure albumen form a precipitate after standing a time. Goulard's extract (a saturated solution of litharge in hot vinegar) precipitates albumen very speedily.

Most of these and other substances which coagulate albumen also act upon other animal fluids, but Dr. B. considers the coagulation by heat alone and by corrosive sublimate as exclusively belonging to albumen when compared with jelly and mucus. When corrosive sublimate is first added to a solution of albumen and heat afterwards applied, the coagulation is very complete, and the coagulum separable from a very dilute solution, but then it is a solid compound of albumen with oxyd of mercury. The solution of tan, though considered as the appropriate precipitant of jelly, will also affect a solution of albumen, though not to the same degree, and the compound precipitate of tan and the animal matter is not so dense and separable from the liquid when albumen is present.

Almost every metallic solution is precipitated by albumen,^b and this precipitate then consists of acid, metallic oxyd and albumen, but it is again soluble more or less completely in an excess of albumen. Hence it may be inferred

that it is the albumen which holds in solution the oxyd of iron met with in the blood.

Mr. Brande has given some very valuable facts respecting the detection of small quantities of albumen by the galvanic action.^c When the conductors from a galvanic battery are brought near each other in white of egg, an immediate and rapid coagulation takes place at the negative wire but only a thin film of albumen forms at the positive wire. This has been explained on an idea first suggested by Dr. Thompson, namely that the fluidity of albumen depends on the presence of alkaline matter, the separation of which at the negative pole causes the albumen to assume a solid form.

Pursuing this idea, Mr. Brande coagulated some white of egg by heat and then extracted by hot water that portion of the coagulum which (as observed by Dr. Bostock) is again soluble in water, this solution was then exposed to the galvanic action, and a copious coagulation took place at the negative pole.

The decomposition of liquid albumen by voltaic electricity takes place however in very different ways according to the power employed. When the power is comparatively high the coagulation goes on rapidly at the negative pole and only slowly at the positive; whereas with an extremely low power, the coagulation is comparatively rapid at the positive surface, whilst an alkaline solution of albumen continues to surround the negative pole. It would appear also that gelatine is not precipitated by galvanic action as albumen is; which may afford an useful mode of analyzing and separating a mixture of these two fluids, and also of distinguishing a solution of albumen in alkali (such as exists in the serum of blood) from real jelly, which, when concentrated, it resembles, in having a gelatinous appearance. Thus on mixing a solution of isinglass with serum of blood and exposing the mixture to galvanic action, the albumen of the serum was first separated by this means, after which an addition of galls detected the jelly of the isinglass apparently unaltered.

Professor Berzelius in his elaborate analysis of the blood^d (which will be further noticed under that article) finds that a solution of albumen, such as exists in the serum of blood, will readily dissolve many metallic salts particularly the suboxyds of iron. This solution is readily made, and is green when the black oxyd is used and becomes yellow by exposure

^a Phil. Journ. vol. 11. and 14.

^b Thenard. An. Chim. tom. 67.

^c Phil. Trans. for 1809 & 1812.

^d Medico-Chirurgical Transactions, vol. 3.

to the air, with deposition of red oxyd. A mineral acid precipitates the albumen colourless and retains the iron in solution. The prussiates alone do not disturb the solution of iron in albumen, but on adding a little muriatic acid, an exquisitely beautiful blue precipitate falls down, which is a compound of Prussian blue and albumen.

The same author finds (as indeed has every other) that there appears to be very little difference between fibrin and albumen except in the mere circumstance that albumen does not coagulate spontaneously, and albumen seems to be intermediate between fibrin and the colouring matter of blood. The ash of coloured albumen is white; it contains no iron, but shews a little soda, phosphate, and carbonate of lime, and some magnesia.

The ultimate analysis of albumen when decomposed by combustion with oxymuriate of potash is thus given by Messrs. Gay Lussac and Thenard.^a 100 parts of albumen supposed to be free from all earthy and metallic parts, contain,

Of carbon	52.883
Of oxygen and hydrogen in the } proportions to constitute water	27.127
Of hydrogen in excess	4.285
Of azote	15.705
	100.000

The albumen here employed was white of egg, dried as much as possible in a boiling water heat. Sixteen grammes left after calcination in open fire 0.976 of a gramme.

In the results of this analysis of the proportion of its elementary ingredients it is found to agree most closely with fibrin. (See *Analysis in this Appendix.*)

ALCOHOL AND ETHER.

Muriat of lime affords a still better means of bringing alcohol to the highest degree of rectification than subcarbonate of potash, or it may be used after the alkali has ceased to exert its power. Dry muriat of lime added to alcohol already highly rectified will produce two liquors, the lowest a watery solution of the salt, the highest a spirit which when carefully decanted and redistilled at a gentle heat, will afford alcohol of extreme purity and strength, the first distilled portion is the lightest and therefore the purest.

An elaborate series of experiments on the ultimate analysis of alcohol and ether, has been undertaken by Th. de Saussure,^c in methods

somewhat differing from that of Lavoisier. The operation of analysis consisted fundamentally in combining the alcohol with the utmost possible quantity of oxygen, so as to reduce it entirely into carbonic acid and water, (which indeed was that of Lavoisier) and calculating from the known proportions of these substances, those of the respective constituent parts of alcohol.

Several data must be laid down as elements of these calculations, and those assumed by M. de Saussure are the following:

100. parts of water contain by weight 88. of oxygen and 12 of hydrogen, 2. parts by measure of hydrogen saturate one measure of oxygen to form water.^b

1000. cub. inch. of hydrogen gas (Bar. 28°. Ther. 10°. Reau.) at the point of extreme dryness weigh 34.303 grs. (French weights & measures.)

1000. cub. inch. of oxygen gas under the same heat and pressure but at the term of ex-moisture weigh 512.37 grs.

1000. cub. inch. of carbonic acid, under the same circumstances as the last, weigh 693.71 grs.

Carbonic acid contains its own bulk of oxygen gas.

100. parts by weight of carbonic acid gas at the point of extreme humidity contain 26. parts of carbon.

The alcohol here used had the specific gravity of 0.792 at 16°. Reau. (68°. Fahr.) and was obtained by distilling common spirit of wine from half its weight of muriat of lime dried nearly at a red heat, and drawing off only half the liquor; and again distilling this from its own weight of muriat of lime and drawing only half.

This alcohol was burned in three different ways.

The first, (which was that of Lavoisier) was to burn it in a lamp under a receiver filled with oxygen gas.

The second, was to detonate its gaseous vapour with oxygen gas in Volta's Eudiometer.

The third, was to decompose it by passing it through a red hot porcelain tube.

The exact process of the first mode differed in some particulars from that of Lavoisier. From this the composition of 100 parts of the alcohol used was estimated as follows:

Carbon	36.890
Hydrogen	9.365
Oxygen and hydrogen as water	53.745

100.000

^a Recherches Physico-Chimiques, tom. 2.

^b L. Phys. tom. 64, or Phil. Journ. vol. 21.

Of the above 53.745 of water, the oxygen is 47.296 and the hydrogen therefore is 6.449, which added to the 9.365, gives 15.814 for the entire hydrogen.

As these results differed considerably from those of Lavoisier, M. de Saussure repeated the experiment with alcohol rectified by distillation alone without addition; but after making due allowance for the proportion of water in this lower alcohol (from Richter's tables) the composition of the pure alcohol contained therein, hardly differed from the former where this alcohol alone was employed. Hence the comparative accuracy of the experiments was proved, and also the important point was proved that alcohol thus highly rectified by distillation twice from muriatic of lime, does not sensibly approach to the nature of ether, as has been supposed.

The second mode of analysis was by detonating the vapour of this alcohol with oxygen in Volta's tube by the electric spark. This however would not detonate without the mixture of a little hydrogen. The fumes left after the detonation had no smell of burning spirits. After all calculations the composition of the alcohol from this experiment is :

Carbon . . .	42.82
Hydrogen . . .	15.82
Oxygen . . .	41.36
	100.00

The third mode of analysis was by passing the alcohol through a red-hot tube and examining all the products, an operation of great length and very complicated. Several foreign substances were thus detected in the alcohol, such as potash, lime, silex and acetic acid, but in very minute quantity. The *immediate* products of the whole process were a carburetted hydrogen gas, water, oil, charcoal and ashes. Of these the gas was in by far the greatest proportion, and was analyzed separately.

The composition of alcohol derived from this last process, agreed very nearly with the last mentioned, it was :

Carbon . . .	43.65
Oxygen . . .	37.85
Hydrogen . . .	14.95
Nitrogen . . .	3.51
Ashes . . .	0.04
	100.00

This result however shews a small propor-

tion of nitrogen which escaped notice in the former experiments.

Sulphuric Ether. This fluid was analyzed also by M. Theod. de Saussure, both by transmission through a red-hot porcelain tube, and by the detonation of its elastic vapour. In the former method the ether was entirely decomposed and the immediate products were a large quantity of oxycarburetted gas, amounting to near nine tenths of the weight of the ether, some oil and some charcoal deposited in the tube.

The ultimate analysis of ether gave the following results :

100 parts of ether contain	
Carbon . . .	59.
Oxygen . . .	19
Hydrogen . . .	22
	100

Hence in equal weights ether contains much more carbon and hydrogen than alcohol, but less oxygen. The author endeavoured to ascertain what quantity of ether a determinate weight of alcohol would produce. By distilling alcohol first with sulphuric acid and then rectifying the residue by several alternate distillations from a solution of potash and fresh sulphuric acid, he obtained from 100 parts by weight of common spirit of wine, 25.25 parts of ether in the first process; 10.3 in the second; and 3.2 in the third, reckoning as part of the product the actual loss of weight during each distillation, which is here considered as etherized vapour. The sum of these products and losses of ether amounts to 38.75, which is nearly half the weight of the pure alcohol contained in the 100 parts of the common spirit of wine. These experiments, like most of the others made on these substances with a view of analysis, are confessedly only approximations to accuracy, being laborious and complicated.

Nitric Ether. An elaborate and important series of experiments on this and many other ethers has been performed by M. Thenard,^c from the particulars of which the following description of its properties is deduced.

Nitric ether is a very inflammable, odorous, pungent liquid, somewhat lighter than alcohol, and soluble in this fluid in all proportions; almost insoluble in water, though when mixed with it giving it the smell of rennet apples; decomposable by heat and forming nitrous and acetic acid; soluble in every gas, and with

^c Mem. d'Arcueil. tom. 1.

the nitrous and acetous acid gasses, producing a most intimate combination which can with difficulty be separated by alkalies. Nitric ether reduced to its ultimate elements is thus composed :

Azote	14.49
Carbon	28.65
Oxygen	48.52
Hydrogen	8.54
	100.00

Nitric ether is obtained by distilling equal parts of highly rectified alcohol and nitric acid. 1000. parts of the mixture give about 160 of pure ether, but for this purpose the gaseous product, which is very abundant, must be passed through five or six bottles half full of saturated brine, and cooled by ice or snow and salt, or some similar freezing mixture; and the retort itself must be frequently cooled with cold water to moderate the action of its contents. All the ethereal liquors contained in the bottles must be then collected and freed from their acid, by being shaken in a bottle in contact with lime.

The gas disengaged by the first distillation is very abundant, and consists of much nitrous oxyd, a little nitrous gas, azote, nitric, acetic, and carbonic acids, together with a good deal of ether, most of which however is separated by the intense cold of the apparatus.

If the distillation is stopped when no more ether is given over, the residue contains nearly three fifths of the whole mixture, and is yellowish, acid, alcoholic, and contains nitric and acetic acids.

Nitric ether, or etherized nitrous gas, may be decomposed by potash, in the latter case by frequent agitation with a solution of the alkali, in the former by being added to an alcoholic solution of potash. After a day or two the decomposition is compleat, and the residue contains alcohol, nitrite and acetite of potash.

Muriatic Ether. The properties of this ether have also been examined by M. Thenard. Muriatic ether may be made in various ways, with more or less ease, both by distilling alcohol and the metallic muriats, and also by the direct union of muriatic acid and alcohol, as we have mentioned in the Chem. Dictionary. M. Thenard prepared it in the following way: equal volumes of alcohol and muriatic acid both highly concentrated, were put into a retort (with a few grains of sand at the bottom to avoid the spirting up of the contents when

boiling) and well shaken, and then set over a furnace. A tube of safety connected the retort with a tubulated receiver, double the size of the retort, and partly filled with water so as to immerse the end of the tube. Another tube proceeded from the receiver to the first of a series of bottles also filled with water. The retort was gently heated, and bubbles of etherized gas soon appeared, mixed with some alcohol, acid, and water, all of which last were detained in the receiver, whilst the pure gaseous ether passed on in great abundance in proportion as the water became saturated with it. This gas is colourless, strongly ethereal to the smell, and tastes saccharine, particularly when dissolved in water. It has no action on litmus, violets, nor lime-water. Its sp. gr. is 2.219 at 64° Fahr. (common air being 1.00) and at a medium pressure and the above temperature is soluble in its own bulk of water. It becomes liquid at 52° Fahr. and hence the liquid ether may easily be obtained separate, by conducting the gas into an empty vessel surrounded with ice. The liquid ether also has no effect on litmus. Its specific gravity at 41° F. is .874. When poured on the hand it immediately boils and evaporates, producing much cold. It does not congeal at — 20° F. At a medium temperature and in a short time this ether, whether gaseous or liquid, shews no trace of muriatic acid either by the action of alkalies or by nitrat of silver; but the moment that this ether is burned, so large a quantity of muriatic acid is set at liberty as to diffuse its suffocating vapour all around and to be manifested by all the proper chemical tests. It is therefore a peculiar property of this ether to contain a large quantity of muriatic acid in a state which is not readily detected except by combustion.

Muriatic ether, both liquid and gaseous, is slowly absorbed by a solution of potash in water or in alcohol, at a low temperature. At first no muriatic acid appears to combine with the alkali, but after a considerable time a little of the acid separates, though partially, and becomes sensible by the test of nitrated silver. But by raising the temperature this separation of the acid becomes much more rapid.

The sulphuric and nitric acids in like manner have but little action on the ether when cold, but decompose it rapidly when heated. On the other hand oxymuriatic gas and muriatic ether, act upon each other immediately at a common temperature, and a large quantity of muriatic acid appears.

Some experiments have been made with the same view as those above mentioned, by M. Boullay.^d The muriatic ether was prepared in the following way. Muriatic acid gas, disengaged from dried common salt and sulphuric acid, was passed through 1000. parts of pure alcohol by a suitable apparatus, and 680 parts of the acid gas were absorbed, during which the temperature (at first 50°. F.) was raised to 75°. F. The alcohol thus saturated with muriatic acid gas was colourless, of an oily consistence, of 1.134 sp. gr. smoking when exposed to air, miscible with water, but with the disengagement of heat and bubbles of air smelling strongly of ether. This muriated alcohol was distilled separately, and the products received first into an empty bottle, kept at the temperature of 14°. to 17°. F. by muriat of lime and snow, and beyond this, into water. The distillation from the retort took place at about 86°. and most of the etherized gas condensed in the empty bottle into a liquid, which after washing with potash appeared to be pure muriatic ether.

M. Thenard states in a note (Mem. Arcueil, tom. I. page 154) his surprize at learning that his experiments on the production of muriatic ether by muriatic acid and alcohol alone, which he considered as nearly original, had been anticipated by Basse, a chemist of Hameln, who prepared the ether by sulphuric acid, alcohol, and common salt, and by Gehlen who had repeated Basse's experiment. It appears however that Scheele discovered most of the remarkable properties of this ether, and pointed out its gaseous form, its peculiar sensible qualities, its giving no indication of acidity by litmus or nitrat of silver *before* combustion, but abundantly *afterwards*.

Muriatic ether is also made (as mentioned in the Chem. Dicty.) by distilling some of the metallic muriats or *butters* with alcohol, a process described by Scheele, Rouelle and Courtanvaux. This was repeated by Thenard with a little variation. A mixture was made in a retort of 7 parts of highly rectified alcohol and 12 parts of muriat of tin. A tubulated long-necked matrass was connected with the retort, and a Woulfe's apparatus was annexed. The matrass was empty and kept cool, the other bottles were full of water. On mixing the materials, a hissing noise like the quenching of hot iron in cold water was heard, and a very great heat was excited. The distillation was continued at a boiling heat till nearly all the

alcohol was driven over. No gas whatever was generated. In the retort was left a hard yellow muriat of tin; the matrass contained two strata of liquids, the lower, which was in small quantity was a solution of muriat of tin; and the upper was a thick liquid strongly ethereal and alcoholic, with a sharp metallic taste, reddening litmus, and depositing oxyd of tin on saturation with alkali. This liquid was diluted with water and redistilled, and the products were alcohol, etherized gas and muriat of tin. The etherized gas on further examination was nearly, if not absolutely, identical with the gaseous muriatic ether obtained by the former processes.

M. Thenard in a subsequent memoir gives his experiments on the ultimate analysis of muriatic ether, though confessedly imperfect. An essential part of this inquiry was to discover the proportion of muriatic acid, or its elements, combined in the ether. For this purpose a given quantity of muriatic acid and alcohol were put into a retort and distilled, with proper precautions to collect all the products, liquid and gaseous, and these were afterwards separately examined. The quantity of muriatic acid entering into the composition of the ether was estimated by comparing the quantity of potash required to saturate the acid in the retort before and after the distillation, all the loss of acid from the retort being supposed to enter into the composition of the ether. From these data it would appear that muriatic ether contains full 30 per cent. of its weight of muriatic acid of an equal degree of concentration as exists in fused muriat of potash.

Action of Oxymuriatic Acid upon Alcohol.

The mutual action of these two substances was first examined by Scheele, and afterwards by Berthollet, Pelletier, and other chemists. They have noticed the production of a green oil in the process, and of a quantity of ether. M. Thenard in repeating this experiment employed 300 parts of alcohol, and passed through it the oxymuriatic gas arising from 1750 parts of common salt, 450 of black oxyd of manganese, and 800 parts of sulphuric acid diluted with as much water. The gas was first washed by transmission through water, and then sent into the alcohol, and the whole was absorbed. The liquor contained a greenish-white oil, and a great excess of muriatic acid. On rectification with alkali no ether was obtained, but only an alcoholic liquor holding more of

^d An. Chim. tom. 63.

the same oil in solution. This in some respect agrees with the result of Dollfuss's experiments before mentioned; * so that it seems still doubtful whether true muriatic ether is formed by the mere transmission of oxymuriatic acid through alcohol.

Phosphoric Ether.

The following process is given by M. Boullay^f for the preparation of phosphoric ether, the existence of which had been doubted by several chemists. To a tubulated retort placed on a sand-bath was joined a tubulated receiver connected with a Woulfe's bottle full of lime water and with a pneumatic apparatus. Into the retort were put 500 grammes of pure phosphoric acid, made by acidifying phosphorus by nitric acid, vitrifying the acid, redissolving and evaporating it to the consistence of honey. A glass vessel similar to the *Acid-Holder*, open at both ends and terminating at one end in a long tube with a stop cock, was fitted to the tubulure of the retort, the lengthened tube dipping into the phosphoric acid. The receiver being kept cool by a mixture of salt and ice, the acid in the retort was heated to about 245°. Fahr. Then 500 grammes of alcohol were let down, drop by drop, into the heated phosphoric acid. A violent ebullition took place on the mixture, which turned black, and numerous streaks of condensed vapour immediately appeared on the neck of the retort. The fire was kept up till the contents of the retort were dry.

There passed into the receiver,

1st. 120 grammes of weakly etherized alcohol.

2d. 260 grammes of a clear, light liquid, smelling much more strongly etherized than the last.

3d. 60 grammes of water saturated with ether, on which floated about four grammes of a yellow empyreumatic liquid resembling oil of wine.

4th. Another liquid insupportably fetid, reddening litmus and effervescing with carbonate of potash. When saturated with this alkali it afforded acetite of potash.

The lime water became turbid only at the end of the distillation.

The gas collected had a sweet penetrating smell, burning with a white flame and depositing a copious black soot.

The two first products of the distillation being mixed and rectified by gentle distillation from muriat of lime, gave 60 grammes of a

very pure ether strongly resembling sulphuric ether, in its partial solubility in water, rapid evaporation in the air, burning with a white flame and smoke, and leaving no marks of acidity when kindled on the surface of water.

Alcohol and the Vegetable Acids.

Most of the vegetable acids dissolve in alcohol, but the spirit is separable again by distillation in an unaltered state from all but the acetic acid, and even this latter will not convert alcohol into ether without frequent cohobation, or the use of some of the dry acetites.

But if a small portion of any of the concentrated mineral acids be added to the vegetable acid and alcohol before distillation, a most striking difference of result is observed. The alcohol is changed more or less completely into an ether or a substance resembling ether, consisting of an intimate combination of the alcohol and acid, which hardly if at all shews any acid properties before combustion, but gives a large quantity of acid afterwards. This curious subject was first undertaken by Scheele, who shewed by experiment the facility with which the addition of a little muriatic acid promotes the separation of acetic ether from acetic acid and alcohol, and observed a singular product obtained in this method from benzoic acid, muriatic acid and alcohol, but failed in procuring any particular results from the tartaric, citric, boracic and succinic acids. This subject has also been examined with some minuteness by M. Thenard.^g

Some of the experiments we shall mention.

Benzoic Acid, Alcohol and Muriatic Acid.

30 parts of benzoic acid, 60 of alcohol, and 15 of concentrated muriatic acid, were distilled till two thirds of the ingredients had passed over. No gas but common air appeared, and scarcely a trace of muriatic ether. The first distilled product was only alcohol, but afterwards a peculiar matter came over dissolved in the spirit but separable by water. The retort also contained much of the same substance which had congealed to the bottom. It was separated from all the other matters by washing with hot water in which itself was hardly soluble. This substance was yellowish, pungent, somewhat heavier than water, fusible at from 76°. to 86°. F. and volatile at about 176°. F. it was acid, oleaginous, nearly insoluble in cold water, but considerably soluble in hot water and in alcohol, from which last it was precipitable by water. When the excess of

* Chem. Dict. article *Ether*.

^f An. Chim. tom. 62, p. 192.

^g Mem. Arcueil. tom. 2.

acid was saturated with an alkali it still remained white, pungent, and odorous, and quite liquid at a common temperature. When long agitated with liquid potash it gradually was absorbed without the disengagement of any gas, and appeared to be resolved into alcohol and benzoic acid, but no muriatic, and yet it cannot be formed by the direct distillation of benzoic acid and alcohol, without the intervention of the muriatic acid.

The citric, oxalic, and malic acids, distilled with alcohol and a little sulphuric acid, all gave a peculiar substance somewhat resembling that from the benzoic acid.

Acetic Ether. 20 parts of acetic acid congealable at 32° F. were distilled once with 30 parts of alcohol of .800 sp. gr. It required much heat to bring the mixture to boiling, and only a very little acetic ether was produced.

The same experiment was repeated with the addition of 5 parts of strong sulphuric acid: 19 parts of the acetic acid disappeared, the ether was produced with singular ease and almost without heat, and as much as 40 parts were obtained: this appears to be a very simple and excellent process, and the ether may be rectified easily by a little potash even without a second distillation.

Acetic ether may also be made very well by Scheele's method, (*Chem. Dict. art. Ether.*) The following are given by M. Thenard as good proportions: 3 parts of acetate of potash, 3 parts of strong alcohol, and 2 parts of concentrated sulphuric acid, distilled to dryness. The product again slowly distilled with a fifth of its weight of fresh sulphuric acid, will give as much rectified acetic ether as the alcohol employed. The sulphuric acid should be always concentrated. Any other neutral acetite will answer the same purpose, and the dose of sulphuric acid should be somewhat more than will saturate the base of the acetite. The neutral acetites distilled *per se* yield a peculiar substance called *Pyro-Acetic Spirit*, already described in the article *Acetic Acid* in this appendix. M. Thenard infers as a general law, from these and other experiments, that when the vegetable acids are pure, none of them, except the acetic, will combine with alcohol in such a way as to lose their acid properties; but when a mineral acid capable of strongly condensing alcohol is added, all these vegetable acids acquire the property of uniting with alcohol into a peculiar compound which shews no acidity till the compound is again

decomposed by heat or alkalies, and which does not contain any of the mineral acid necessary to its formation.

Alcohol—how produced from fermented liquors.

In our original article (*Fermentation, vol. I. p. 431*) we mentioned that a question has arisen whether alcohol exists ready formed in fermented liquors, or whether it is a product generated from them by the act of distillation. Mr. Brande has given some experiments on this subject in which he favours the former opinion.^a Fabbroni who advanced the latter of these two opinions, asserts that though dry carbonate of potash will not separate any alcohol from wine in its natural state, yet if as little as a hundredth part of alcohol is purposely added to wine, this addition will be made apparent by mixing dry subcarbonate of potash to the wine. Mr. Brande however did not find this to be the case with the wines which he employed; for when 4 oz. of the dry alkali were added to 8 oz. of port wine, both pure, and mixed with $\frac{1}{8}$ of alcohol, no separation of spirit took place in either instance, but the mixture in both cases divided itself into two portions, the lower of which was a saturated solution of the alkali, and the upper was a gelatinous mass containing apparently all the colour and extract of the wine, uniformly and undistinguishably mixed with the spirit. Nevertheless as it was found that very exactly the same proportion of alcohol was yielded by pure wine, when distilled at different temperatures, (the boiling point being raised artificially in some of the experiments by adding muriatic of lime) the author conceives that this is a sufficient proof that the alcohol is not *formed* but merely *expelled* from the wine by distillation, since if it had been actually formed in the process, he supposes that a change in the boiling temperature must have influenced the product of alcohol in one way or other.

A much more satisfactory proof of this opinion with regard to the formation of alcohol is however furnished by the same chemist in his last paper, in which he first precipitates all the extractive and colouring matter from wine by the subacetate of lead, and then the addition of the alkali separates the alcohol from the wine thus clarified in a very distinct manner. One measure of a saturated solution of the salt of lead added to 8 measures of port wine, and shaken for a few minutes and thrown on a filter, gave a perfectly clear and colourless

^a Phil. Trans. for 1811 & 1813.

liquid, from which on the addition of dry subcarbonat of potash the alcohol separated rapidly. Mr. Brande found by experiments with alcohol and coloured water, that this mode separated the spirit almost totally from the mixture, whence it is reasonable to infer that no spirit whatever is generated by distillation, but only expelled from the fermented liquor.

The subacetate of lead is prepared by boiling two parts of sugar of lead with one of finely powdered litharge, in six parts of water. It should be kept carefully excluded from the air which is constantly converting it to insoluble carbonat of lead. The effect of this subacetate in separating all vegetable matter from infusions of vegetables has been long noticed by Dr. Bostock and other experimental chemists.

ALCOHOL OF SULPHUR. See SULPHUR, ALCOHOL OF.

ALKALI (FIXED.)

Potash and soda prepared from the carbonats of these alkalies by lime, the caustic alkaline solution being evaporated to dryness, redissolved in alcohol, and again dried and heated to redness, have long been considered as being in as high a state of purity as can be produced by chemical means. See the Article (*Potash*) *Chem. Dict. Vol. II.*

But a most important discovery has lately been made which affects the results of all the analyses of the neutral salts with a basis of potash or soda, and indeed is peculiarly satisfactory, as it explains the anomaly, before unaccountable, of the great difference in the estimation of these salts when the experiments are made with the dry alkaline carbonats or the dry caustic alkali. The discovery is, that the caustic fixed alkali prepared with the utmost care and brought to a state of fusion in a red heat, is not the simple alkali, but contains a considerable proportion of *Water*, which cannot be expelled by any length of fusion, though it does not accompany the alkali when neutralized with an acid and again brought to the heat of ignition. Hence if in any analytical experiment a given weight of ignited caustic alkali is saturated with an acid, and the entire neutral salt thence resulting is ignited and weighed, it is obvious that if the caustic alkali employed be considered as mere alkali, the proportion of alkali in the neutral salt will be much overrated, and therefore the quantity of acid required to saturate 100 parts of the alkali will be estimated much lower than the truth.

This anomaly was very accurately stated and

its real cause suggested by M. Darcet, in a Memoir read at the French Institute, January, 1808.^a The experiments of this eminent chemist are (in a few words) the following:—Some very pure subcarbonat of soda was prepared and saturated with a dilute sulphuric acid, containing exactly a tenth part of a pure concentrated sulphuric acid of 1.844 sp. gr. This subcarbonat was found by various analyses to consist of 63.61 of water: 16.04 of carbonic acid, and 20.35 of soda. A hundred grammes of this subcarbonat were exactly saturated by 347 grammes of the dilute sulphuric acid, equal to 34.7 of the concentrated acid; which would give 170.515 of the concentrated acid to saturate 100. of the mere soda in the state in which it exists in the carbonat. On the other hand 100. grammes of caustic soda prepared by alcohol and fused in a silver vessel at a red heat, saturated only 119.6 grammes of the sulphuric acid in one experiment, and 122.4 in another, making a difference of about 50 grammes of acid in the estimated quantity in the two cases. Hence it must follow that the soda prepared by alcohol contains only 71 to 72 per cent. of real alkali in that state in which it exists in the carbonat, both salts being equally ignited, and therefore that which has usually been considered as pure soda, is properly *Hydrat of Soda*, consisting of about 72 of pure soda and 28 of water.

The next experiments on this subject which we shall mention are those of M. Berthollet.^b This eminent philosopher in his *Researches on the Laws of Chemical Affinity*, has taken much pains to determine the respective quantities of most of the acids and bases that saturate each other, and in this enquiry the composition of sulphat of barytes came under particular consideration, as it is a salt very commonly obtained in analytical experiments, and its insolubility renders it a very convenient basis of calculation.

It would appear at first to be a problem of no great difficulty to determine the elements of this salt, and yet the calculations of equally skilful and accurate chemists varied as much as to give a difference of from 67 to 75 per cent. in the proportion of acid, which is much too great to be accounted for from any of the common inaccuracies in chemical experiment.

On further examination M. Berthollet found the cause of this difference to be in the barytes used. He and M. Thenard employed barytes crystallized from its aqueous solution, evaporated to dryness, and strongly ignited. M.

^a An. Chim. tom. 68.

^b Mem. d'Arcueil, tom. 2. p. 50

Berthier, Richter, Bucholz, and other equally distinguished chemists used the barytes prepared from the nitrat of barytes by a strong heat, which destroys the acid and leaves the barytes pure. In the first instance the barytes was more easily fusible than the other, and when cold had the appearance of a semi-transparent glass. The barytes from the nitrat on the other hand required a much greater heat for its fusion, and in melting absorbed a little carbonic acid. By adding a little water to this barytes it became in every respect like the other. The barytes from the watery solution of this earth, was also strongly heated with iron filings in a porcelain retort, and gave out a large quantity of hydrogen. From these facts the author shews that the barytes from the aqueous solution is a *Hydrat* of Barytes, containing about 10 per cent. of water, and the purer form of barytes is that which arises from the calcination of the nitrat.

This discovery led the author to suspect that potash might retain water when heated *per se*, and give it up when it enters into saline combinations. The principal experiment is the following: Some potash was melted in a silver crucible whose weight was known, and kept in fusion till it exhaled white vapours, when the cover was lifted off. The crucible with its contents was weighed when cool, and 15.73 grammes of fused alkali were found to be contained in it. This was dissolved in muriatic acid, and the whole solution with the washings was carefully evaporated and ignited in a platina crucible, till the muriat of potash was in perfect fusion. When cold, the muriat of potash weighed 20.335 grammes, and produced with nitrat of silver 38.586 gr. of well dried luna cornea, which (reckoning 17.5 per cent. of muriatic acid in luna cornea) indicated 6.752 gr. of acid. Consequently the 20.335 of fused muriat of potash consisted of 6.752 of muriatic acid and 13.583 of potash; but 15.73 of fused caustic potash was employed, and hence the difference between 15.73 and 13.583 (2.147) is the quantity of water contained in the fused caustic potash, which gives the proportion of 13.64 of water in 100. of fused potash.

The existence of a large quantity of water of composition in fused potash is also shewn by heating the alkali strongly with iron filings in a porcelain retort, by which a prodigious quantity of hydrogen gas is given out.

It appears however that though fused potash

gives up a large quantity of its water of composition when neutralized by an acid, yet some water is still retained, at least by one or other of the component parts of the compound, for most saline bodies will give hydrogen when heated strongly with iron filings.

Messrs. Gay-Lussac and Thenard,^c have also made several experiments to determine the quantity of water contained in fused caustic alkali prepared with alcohol. A portion of fused potash was carefully weighed in a closed vessel, it was then taken out, put upon a dish of platina, and introduced into a large glass globe nearly full of a measured quantity of carbonic acid, standing over mercury, so that the alkali did not touch any portion of the glass. The alkali was then heated very gradually, when it became white on its surface, softened, rapidly absorbed the carbonic acid gas, and in so doing such a quantity of water was disengaged as to trickle down the sides of the glass globe. The heat was very gradually raised to a cherry red. The water was then absorbed by blotting paper, and the remaining carbonic acid gas measured, and the carbonat of potash weighed.

A similar experiment was performed on fused soda.

The results of these were, that 100 parts of fused potash in combining with carbonic acid, give up 13.596 parts of water; and 100 parts of fused soda give up 22.166.

The next experiment was to combine the alkali with silex by fusion, forming a glass. A given weight of the fused alkali and ignited silex were put into a silver crucible, and some water added to promote an entire mixture of the ingredients, which was then slowly dried and ignited to redness for an hour. The result was a perfect glass, which was weighed. From this experiment, 100. parts of fused potash were found to contain 18.45 of water of composition, and 100. parts of fused soda contain 26.15 of water.

The third experiment was the following: A certain weight of fused potash and of fused soda were saturated with sulphuric acid and the quantity noted. On the other hand known quantities of potassium and sodium were exposed to a moist air in long narrow vessels, till they were converted into their respective alkalies, which were then saturated with the same sulphuric acid as that employed before. Hence supposing the alkali produced from the potassium and sodium to be pure, and free

^c Recherches Physico-Chimiques, tom. 2.

from water of composition, and knowing the quantity of alkali produced by the alkaline basis, it was easy to compare the saturating powers of these alkalies with those of the fused potash and soda prepared by alcohol. From these data 100 parts of fused potash prepared by alcohol contain 20.72 of water of composition: and 100 parts of fused soda contain 23.89 of water.

The authors take as a mean from these experiments (rejecting the first as far as regards the potash as being imperfect) that caustic potash, prepared in the common way by alcohol, and fused at a red heat, contains a fifth of its weight of water; and fused soda a fourth.

We may observe however that these results differ much too widely to be a fair subject for taking an average, except in a very general way. Perhaps, too, it is impossible to fix precisely the quantity of water contained in the fused caustic alkali, as this may vary according to the heat employed and other circumstances. It shews however that this form of alkali is certainly a *Hydrat*, or one that contains a notable quantity of water of composition, and also that no great dependance is to be placed on the accuracy of any calculation on the proportions of the alkaline neutral salts, which is founded on the quantities of the Hydrated Alkali employed.

ALKALINE BASIS. POTASSIUM. SODIUM.

One of the most interesting discoveries of modern chemistry is the decomposition of the fixed alkalies which had often been conjectured to be of a compound nature, but no evidence of the truth of this opinion had ever been given till Sir H. Davy applied to this enquiry the astonishing powers of electro-chemical agency. The researches which he had made on the decomposition of acids and neutral salts by galvanic electricity were full of new and most interesting results, they pointed out a mode of chemical analysis far more powerful than any that had been hitherto undertaken, and the admirable skill in contriving experiments, and sagacity in deducing from them the general laws of chemical decomposition, enabled him to make the brilliant discovery which is the subject of this article. He conjectured that if a freed alkali was an oxyd of some unknown base, it was probable that when it was subjected to the action of opposite electricities, the oxygen of the alkali would be conveyed to the

positive pole, whilst the inflammable base would appear in a separate state at the negative pole.

Some difficulties arise at first in selecting a proper mode of conducting the experiment. When a solution of the alkali was used, the electric power was expended chiefly in the decomposition of the water present; and on the other hand, when the alkali was dry and fused at the time of applying the electric power, it was indeed decomposed, but the basis instantly burnt with a most intense light and flame, and could not be collected. The great difficulty in the experiment was that the alkali, when dried and fused, is a non-conductor of electricity; but it was found that slightly moistening the surface renders it a conductor, and in this state it readily fuses and is decomposed by strong electrical powers.

The basis of potash was thus discovered.^a A small piece of potash which had been exposed for a few seconds to the atmosphere, so as to give conducting powers to the surface, was placed upon an insulated disk of platina, connected with the negative side of the galvanic battery in intense activity, and a platina wire communicating with the positive side was brought into contact with the upper surface of the alkali. A vivid action soon took place. The potash began to fuse at both points of contact; there was a violent effervescence at the positive surface, and at the negative there was no liberation of elastic fluid, but small globules having a high metallic lustre, exactly resembling quicksilver in appearance, were formed, some of which immediately after burnt with explosion and bright flame, while others remained being first tarnished, and finally covered by a white film on their surfaces. The gas liberated at the positive surface was found to be pure oxygen, and the globules were found by numerous experiments to be a peculiar inflammable principle, the *Basis of Potash*. The platina was in no way connected with the result except as a medium for the electric power, for the same effects were produced by substituting copper, gold, plumbago or charcoal.

Soda when acted on in the same manner gave a similar result, but it required a greater intensity of galvanic action to produce the *Basis of Soda*. With a good battery of 100 6-inch plates, the Basis of Potash could be obtained from pieces of the alkali weighing 40 or 50 grains, which made the distance between the opposite wires nearly $\frac{1}{4}$ of an inch; but with the same galvanic power, pieces of soda

^a Phil. Trans. for 1808.

not exceeding 15 or 20 grains could be used, making the distance between the electric poles not more than $\frac{1}{8}$ or $\frac{1}{10}$ of an inch.

The Basis of Potash has been named by the discoverer POTASSIUM, and the Basis of Soda, SODIUM, which term has been universally adopted.

The principal properties of POTASSIUM discovered by Sir H. Davy in his first series of experiments, are the following.

When exposed to the air a white crust rapidly collects on the surface, tarnishing its metallic lustre, and this continues to be produced till the whole is converted to this white crust, which is found to be pure potash. When globules of Potassium are confined in common air, or especially in oxygen, at a common temperature, the same crust is formed, but not being removed by deliquescence, the process is stopped, the interior part of the globule being protected by the crust of regenerated alkali from further change. But when the temperature is raised highly, a rapid and brilliant combustion takes place, and the whole is changed to solid dry potash. Oxygen gas alone is absorbed in this change, the azotic admixture being in no degree affected, and the weight of the potash considerably exceeds that of the potassium decomposed.

Potassium is a soft and malleable solid of the lustre of polished silver at 50° Fahr, at 32° it is hard, brittle, and exhibits in its fractured surface beautiful facets of a perfect metallic whiteness. At 60° it begins to soften and become pasty, and at 100° it is perfectly fluid, so that the globules will run together. At a red heat it is converted into vapour, but in close vessels it condenses unaltered on cooling.

It is a very perfect conductor both of heat and electricity.

One of the most remarkable circumstances relating to potassium is its very great levity. Though resembling the metals in outward appearance, in opacity and lustre, it is not only lighter than any of them, but even than water, ether, naphtha, or almost any known fluid. The exact determination of its specific gravity is attended with difficulty, but Sir H. Davy estimates it at about 0.6 (water being 1.)

The action of water upon potassium is very striking. When a globule of it is touched with a drop of water, it instantly burns with a bright flame and a solution of potash is left. If this simple experiment be performed on paper tinged yellow with turmeric, the spot where the combustion and generation of alkali takes place is

VOL. III.

strongly marked by a deep brick-red stain. When potassium is decomposed by water in close vessels, a gas is found among the products, which is pure hydrogen. So strong is the affinity of potassium for oxygen, that it decomposes water wherever it exists, and thus discovers the watery admixture in the purest alcohol and ether, in both of which the potassium produces potash and hydrogen gas.

In the liquid acids potassium is immediately decomposed. In the sulphuric it produces at once a white salt (probably sulphat of potash) with a yellow coating, which appears to be sulphur. In the nitric and muriatic acids it produces nitrat and muriat of potash.

As potassium cannot exist for a moment unaltered in water or any fluid containing water, nor for any length of time in air, it was a matter of difficulty to find some mode of preserving it. It was found however that naphtha recently distilled will preserve it unchanged for a sufficient length of time, though even in this fluid it gradually oxydates and forms a kind of potash soap with the naphtha, that collects round the globule and prevents it from floating in this fluid. It also slowly forms an alkaline soap when confined in any of the oils.

Potassium unites with many of the metals with great ease, forming very peculiar alloys. It amalgamates readily with mercury and remarkably reduces its fluidity; for when united with 30 times its weight of mercury, the alloy is hard and brittle. The fluid amalgam dissolves all the metals, forming a triple alloy of mercury, potassium and the other metal employed. When the amalgam is thrown into water, a hissing noise is produced, hydrogen gas is given out, potash is generated, and the mercury returns unaltered to its original state.

Potassium will equally well unite with gold, silver and copper, and it is equally separable from these alloys by mere moisture, which regenerates the alkali.

Potassium readily reduces many of the metallic oxyds, and when in excess it unites with the metal thus reduced.

It decomposes the metallic oxyds in flint-glass and green-glass at a low red-heat; but it also gradually changes perfectly unmetallic glass when heated in such vessels, slowly alkalizing itself and corroding the glass.

These are the principal properties of this singular substance as given by the illustrious discoverer in his first memoir on the subject, by which it appears that potassium has by far the strongest affinity for oxygen of any hitherto

E

known substance, and this renders it a most valuable reagent for a variety of interesting chemical decompositions.

Before we proceed with the other properties of potassium we shall describe another method of procuring this substance without the assistance of any galvanic apparatus, and in much larger quantity. This method was found out by Messrs. Gay Lussac and Thenard, soon after Mr. Davy's original discovery of potassium, and is described by them with much minuteness.* It consists in heating iron filings to great intensity in an iron gun-barrel, and then passing melted potash through them. The potash is decomposed, a large quantity of hydrogen gas is given out, and the potassium is condensed at the further extremity of the apparatus. As this, though not very complicated, requires a good many precautions, we shall give the original process with minuteness.

The materials. Iron turnings are preferable to iron wire or nails, as they present a considerable surface and yet allow the alkali to pass freely through them. They should be broken down in a mortar, and any adhering oxyd sifted away. The choice of the alkali is not a matter of indifference. The common potash or pearl-ash always contains a small portion of soda, and hence the caustic potash prepared from it is mixed with a little soda, which causes an alloy of a small quantity of sodium with the potassium obtained. Therefore in delicate experiments of research the potash should be prepared from pure crystallized nitre and cream of tartar ignited together, or from calcined cream of tartar alone, which gives the purest potash known. The alkali should be made caustic with lime in the way mentioned under the article *potash*, (Ch. Dict.) and indeed the extraction of the alkali by alcohol is hardly required, but it should be kept at a red heat for some time just before being used, as the presence of much moisture defeats the object of decomposition of the alkali.

The apparatus consists of a gun-barrel A.B.C. (see plate, fig. 1 and 2.) which should be well cleaned within and then bent in two directions by being heated red-hot at the parts required. The middle of the barrel B.C. which is enclosed in the furnace, must be well covered with a very refractory lute, as it is to undergo a very intense heat for a considerable time, which would soon oxydate and destroy the barrel without such protection. The best lute

is a mixture of pipe clay (or Windsor loam) beat up with a little water, and incorporated with as much sand as possible so as to make it difficult to apply. The only part to be luted is that which lies across the furnace, and to this the lute is to be applied in three or four successive thin coatings, and dried with great care, first for a few days in the shade, and then with a gradual heat, filling up any little cracks in it by some fresh lute. The gun-barrel is then filled with the iron turnings, as far as from B. to C. and is then firmly fixed in the furnace, and afterwards the fragments of recently heated potash are put in, without being much pressed, so as to reach not quite to B. and up to a few inches below A. This requires generally about 3 ounces troy, more or less. As much gas always issues through the other extremity D, to prevent any mischief or loss of potassium when accidentally stopped up, it is of use to adopt a bent glass tube to the upper end of the barrel A. which dips under mercury M. as seen in the plate, fig. 1. and allows of the reflux of any gas from the barrel if necessary.

The apparatus being then put up, a fire is lit in the furnace, and the bellows applied at first very gradually, to prevent the lute from cracking. The recipient G. H. is formed by two copper tubes fitted to each other by grinding, the uppermost of them receiving the end D. of the gun-barrel. A glass tube F. fits into the lower half of the recipient and dips into mercury. The recipient is luted on to the gun-barrel by the same fire-lute. When the fire is well kindled the bellows are to be used vigorously, and the heat raised to a very high degree at the same time that the ends of the barrel that project beyond the fire above and below, are kept cool by wetted cloths. When the fire has been raised to its utmost for some time, the wet cloths are removed only from the upper end of the barrel that contains the potash, and instead of it either a small furnace, or chafing dish or hanging trough of iron, E. filled with hot charcoal, is to be applied so as to cover the lower part of that portion of the barrel that contains the potash, and to melt the alkali, which requires a moderate red heat. The melted alkali then falls down into the lower part of the barrel, which is intensely heated, and passes in the form of vapour through the iron turnings. At first the water which the alkali contains in abundance (though previously fused)

* Recherches Physico-Chimiques, tom. 1.

decomposes upon the iron turnings, and much turbid hydrogen gas comes over. At the same time however the potassium is produced and is also vaporized within the furnace, but immediately condenses, partly in the extremity of the barrel, D. and partly in the copper recipient, all of which are, as before, kept cool by wetted cloths. When the efflux of gas begins to slacken, an additional portion of potash is sent down, by shifting the hanging trough of charcoal a little higher, and so on till the whole has been heated almost to the extremity A. It is of importance not to send over too much alkali at once, as this would damp the heat of the iron turnings, and lessen the product of potassium, and this too is one reason why the potash is put in in large pieces. It is a sign that the operation is going on well when the product of hydrogen at the lower extremity is pretty steady and abundant, but not very cloudy. The distillation is terminated when all the alkali has been successively melted down, which takes about an hour from the time that the gun-barrel is first made white-hot, and it then only remains to collect the product, which requires a little dexterity and caution.

The potassium being volatile condenses for the most part in the end of the barrel at D. and thence falls down into the copper recipient G. H. where it solidifies. To collect it, remove the barrel when the distillation is over, stop the upper end A. with a little lute, and hasten the cooling of the barrel by stripping off the lute and wetting the outside, then pull off the copper recipient (immediately stopping the end D. of the gun-barrel that is thus exposed) separate it into its two parts, pour into each a little naphtha, and detach all the potassium with a knife, throwing it into a bottle of naphtha as soon as separated. As some of the potassium remains in the end of the gun-barrel nearest to the recipient, it is the best way to cut off that end with a file, (as the barrel will never serve for a second operation) and to push out all the potassium into oil with a solid mould made for the purpose. This is generally mixed with a little potash from which it may be freed by melting in oil and pressing the whole.

The product of two experiments is given by the authors, in which it appears, that in one, 70 grammes (about 18 drams troy) of potash was employed of which nearly $\frac{4}{5}$ ths was recovered undecomposed from the iron turnings, and the product of potassium was 15.5 grammes (231 grains troy.) In the other experiment

81. grammes of potash were used, and the product of potassium was 20. 2 grammes or nearly a third more than in the former case.

Sometimes the efflux of hydrogen gas from the lower part of the barrel ceases suddenly, and appears at the upper extremity. This may be owing to the stoppage of the end D. by a collection of condensed potash, when the fire has not been kept hot enough or when the alkali has been sent down too fast. This may sometimes be removed by heating the tube with charcoal on the outside, and melting away the obstruction. But if no gas is sent out from either end, it generally shews that the barrel has partly fused down owing to some imperfection in the lute, in which case the process must be discontinued and renewed afterwards either with a fresh barrel or better luting. If a very large barrel is used, a fresh charge of potash may be thrown into the upper part, and the process kept up for an additional time provided enough of iron turnings are introduced at first.

After the operation, if the gun-barrel is divided in different parts where it has been exposed to the furnace, it is found to contain a very hard agglutinated mass of alkali, oxyd of iron, alloy of iron and potassium, and unaltered iron turnings, which require considerable digestion in water to dissolve out the alkali. The quantity of alkali recovered from the iron, is full half of what has been used, and yet a large portion of the iron turnings retain their metallic appearance and their form, so that there is probably much loss of potassium by its alloy with part of the iron, which returns to the state of potash when moistened.

It may be of some assistance to the chemical operator to give Dr. Henry's very clear directions for preparing potassium, according to a process just described, but with some little variation in the apparatus.^c

The apparatus consists of a common gun-barrel, curved and drawn out at one end to rather a small diameter, (see plate, fig. 3). To one end is adapted an iron tube *a*. with an iron stopper) of the capacity of two cubic inches, for containing the potash. At the bottom of this tube is a small hole *h* through which the potash gradually flows. This tube is shewn separately in fig. 4. To the opposite end of the gun-barrel a tube of safety *e* is to be cemented; and into this a sufficient quantity poured either of mercury or naphtha. Into the gun-barrel $2\frac{1}{2}$ parts of very clean iron turnings

^c Elements of experimental Chemistry, 6th. edition, vol. 1.

are to be introduced and pushed on to the bent part *c*. The tube, carefully luted is then to be placed in a small furnace, nine or ten inches in diameter, and provided with a pair of double blast bellows, the pipe from which is shown at *f*. The next step is to insert the tube *a* in its place, after having put into it $1\frac{1}{4}$ parts of pure potash recently fused. The whole apparatus should be perfectly clean, dry, and impervious to air. A strong heat is now to be excited in the furnace, and while this is doing, the tube containing the potash as well as the opposite end of the barrel should be kept cool by ice. When the barrel has attained a white heat the potash in *a* may be melted by a small portable furnace. It will then flow by the small hole upon the iron turnings. Much hydrogen gas will be evolved, and when this slackens we may remove the small furnace from beneath the tube *a* and increase the heat in the furnace *d*, in order to restore to the iron turnings at *c*, the temperature proper for decomposing more potash. These operations may be repeated alternately till no more gas is produced, but last of all the heat in the furnace should be strongly raised to drive off some of the potassium that adheres strongly to the iron turnings.

When the furnace is quite cold, the safety-tube *e* is to be removed, and its place supplied by an iron plug. If the end of the gun-barrel projecting from this side of the furnace has been kept carefully cooled during the experiment the metal will be found adhering to it in the form of brilliant laminæ. In order to extract it, the gun-barrel is to be cut off at the beginning of the part that has been kept cool, where the greatest quantity will be found. Another portion will be found close to the plug, and this adheres so slightly to the gun-barrel that the least effort serves to detach it. It is even partly oxidated by the air that enters on cooling the furnace, and when the whole is covered with naphtha the oxidized part is detached in laminæ, exposing a white and brilliant metallic surface. The potassium which is condensed nearest the furnace must be separated by a sharp chissel in the largest pieces we can possibly break off. In the middle of the gun-barrel we shall find an alloy of potassium and iron which becomes green on exposure to the air, the potassium returning to the state of potash.

The potassium prepared in this way if the alkali is pure hardly differs from that obtained

by galvanic electricity, except that its specific gravity is somewhat higher, being to that of water as 796. to 1000.

Having already described the leading properties of potassium as first observed by Sir H. Davy, we shall proceed to give an abstract of a very long and minute series of experiments on the same subject carried on by Messrs. Gay Lussac, and Thenard,^a most of which furnish results very nearly similar to those of the eminent discoverer of the alkaline metals, but others are different and throw new light on the nature of these curious bodies.

Action of Water on Potassium. When a little water is confined in a jar over mercury, and a portion of potassium is passed up (enclosed in paper) the potassium swims on the water, moves about and lessens rapidly, and soon disappears, leaving the water very alkaline, and a considerable quantity of hydrogen gas is produced. When this experiment is performed, merely by throwing some pieces of potassium on water they soon become red hot while decomposing on its surface, which forms an amusing experiment. To determine the exact proportion of hydrogen produced by the conversion of potassium into potash by means of water, a small iron tube was filled with 2.213 grammes of potassium, and covered with a glass plate, and thus introduced under a bell-glass full of water. The decomposition took place with great rapidity, and, when complete, the hydrogen was measured and found to be 0.666 litre at 15° centigrade therm. and 0.7455^a metre bar. The experiment was repeated with the same result, whence it follows that 100 parts by weight of potassium absorb 19.945 parts of oxygen to pass to the state of potash; and hence 100. parts of potash consist of 83.371 of potassium, and 16.629 of oxygen. These proportions closely correspond with those given by Davy and Berzelius.^b

Messrs. Gay Lussac, and Thenard give a simple method of dividing potassium into equal portions without the trouble and loss attending the process of weighing this decomposable substance, namely, by compressing it into a cavity made in a small block of brass, on which another block exactly fits so as to exclude every atom of potassium except that which fills the cavity. The quantity of hydrogen given by this portion of potassium in ten different experiments varied only from 78.5 to 79.4 measures, and hence assuming 79. as the average, and comparing this result with the former above mentioned

^a Recherches.

^b Ann. Chim. Tom. 80. p. 245.

(in which 2.213 grammes of potassium gave .666 litre of hydrogen) the weight of the portion of potassium filling the cavity in the brass was pretty exactly estimated at 0.0212 gramme. This quantity was therefore the standard of all the subsequent experiments.

Potassium and Oxygen. If potassium is confined in contact with oxygen at a common temperature and kept at rest for some days, it gradually loses its metallic appearance, and is converted entirely into a grey substance. But if the temperature is a little raised or the surface of the metal renewed, it takes fire and the combustion goes on rapidly.

Oxyds of Potassium. There are certainly two distinct oxyds of potassium, and probably three, namely, the suboxyd, the alkali, and the peroxyd.

The suboxyd is a bluish-grey very brittle substance, softer than wax, easily fusible, so inflammable as to take fire in oxygen or even in common air at about 70° Fahr. decomposable by water into alkali, and giving out hydrogen like potassium but in smaller quantity. It is therefore in a lower state of oxydation than the alkali. This suboxyd is produced by confining potassium for some days in an empty phial closed with a cork, the pores of which admit such a very gradual supply of air and moisture as suits the slow and inferior state of oxydation required. It appears however doubtful whether this suboxyd may not be a mixture of potassium and potash, and it has certainly not been obtained sufficiently uniform to allow of its precise degree of oxydation to be well ascertained.*

The second oxyd of potassium is the alkali itself, the composition of which has already been mentioned. This oxyd, the alkali, is always produced, whenever potassium or any of its oxyds come in contact with water. When produced from potassium or the suboxyd just described, an evolution of hydrogen attends the alkalization of the metal, owing doubtless to the decomposition of water: when produced by moistening the peroxyd, the generation of the alkali is attended with the evolution of that portion of oxygen which constitutes the difference between the alkali and the peroxyd, but in either case the contact of water and of potassium in any form determines the formation of the alkali. In this way of forming the alkali it always unites with that portion of water of composition (amounting to about 18 per cent.) which, as has been mentioned in the beginning

of this article, is inseparable from caustic potash prepared by watery solution, even when it has been dried by fusion in a full red heat, and constitutes not properly pure potash, but hydrat of potash. The pure potash can only be obtained by heating the yellow peroxyd to be now described.

The orange-yellow peroxyd of potassium is prepared immediately by igniting potassium in oxygen, or even in common air. The discovery of the real nature of this oxyd, and of its containing more oxygen than the alkali does, is due to the eminent French chemists already mentioned. There is however some difficulty in performing the combustion accurately. If the potassium is burned upon glass or platina, these are both attacked by the oxyd assisted by the great heat generated, and incorrect results follow. A support of silver answers better, though with some risk of its fusion, or as Sir H. Davy recommends, the potassium may be laid in a small dish of platina, coated over with melted muriat of potash, which is not acted on by potassium or any of its oxyds. The French chemists observe that much of the inconvenience of a platina support may be avoided by using potassium that has been in oil, as it then burns at a lower temperature, or still better by employing the suboxyd which inflames spontaneously in oxygen. They give the results of eight different experiments on the combustion of the same quantity of potassium in a glass vessel full of dry oxygen confined over mercury, the potassium being laid in some experiments on glass, in others on platina, in others on silver. The yellow oxyd thence produced was then thrown into water, by which it passed to the state of alkali, giving out all its excess of oxygen. There is so little agreement in these experiments as to the entire quantity of oxygen absorbed by the potassium, that the composition of the peroxyd cannot be deduced from them. The largest quantity of oxygen absorbed (which is obviously nearest the true estimation) was pretty exactly twice as much as that portion required to convert the given weight of potassium into potash, and the experiments were so far satisfactory, that after the yellow oxyd was plunged into water and had parted with its excess of oxygen, the remainder which entered into the constitution of the alkali was nearly the same in each experiment. This peroxyd is fusible at a lower heat than hydrat of potash, and crystallizes in laminæ by cooling. The colour is yellow when pure but brownish when mixed with oxyd of

* Davy.

platina. When thrown into water it gives out pure oxygen gas, and passes to the state of potash as before mentioned. When it is heated very strongly upon a platina support protected by muriat of potash, oxygen gas is given out,^c and there remains a grey difficulty-fusible substance, vitreous in its fracture which dissolves in water with much heat but without any effervescence, and renders the water alkaline. This grey vitreous substance is considered by Sir H. Davy as pure potash, free from water or any foreign body, and it is the only known method of obtaining quite pure uncombined potash.

This yellow oxyd has a very striking action on all combustible bodies, to all of which it affords its excess of oxygen: in doing so it returns to the state of potash, and the alkali thus generated often unites with some or other of the products. Some particulars of these experiments we shall mention.^d

Phosphorus heated with the peroxyd in an atmosphere of azotic gas produced a very vivid combustion, so as to redden the whole of the platina capsule in which it was contained. The azote was unchanged. Part of the phosphorus was burnt and part only volatilized. The product did not effervesce with water and with difficulty dissolved in it, though the salts of lime and barytes gave considerable precipitates. The product of this combustion was probably subphosphat of potash.

Sulphur heated in like manner with the peroxyd gave a compound which no longer effervesced with water (and therefore contained no uncombined oxygen) and smelt of liver of sulphur, and at the same time gave a copious precipitate with nitrat of barytes, and hence contained a mixture of a little sulphuret of potash with much sulphat.

Charcoal and the peroxyd heated together gave carbonat of potash.

The following metals, namely, tin, arsenic, antimony, zinc, copper, bismuth, lead and iron, all in fine filings, were separately heated with the peroxyd. In all the peroxyd was reduced to the state of potash but with some variation in the attending circumstances. With the tin, antimony, and arsenic, there was a great disengagement of heat and light, particularly with the former, so that both the capsule of platina on which the materials were placed and the glass vessel that confined them were made red-hot. The zinc and copper were but feebly ignited, and

the bismuth, lead and iron not at all. The heat was applied in all these cases with a spirit lamp on the outside of the glass vessel. By putting the product in water all the metallic oxyds were obtained except those soluble in the alkali generated in the experiment.

The peroxyd and potassium heated together in the same way produced potash with much disengagement of light and heat.

The peroxyd was introduced into an atmosphere of hydrogen confined by mercury. No effect was produced at a common temperature, but on heating it a rapid absorption of gas took place with abundance of moisture which streamed down the sides of the vessel, the peroxyd whitened and gradually became changed into potash. No light was disengaged.

Phosphuretted and sulphuretted hydrogen heated with the peroxyd produced in like manner water and potash, and sulphuret and phosphuret of potash.

With ammoniacal gas and the peroxyd the products were water and azotic gas.

The peroxyd was heated with muriatic acid gas. Much of the gas was absorbed, drops of water trickled down the sides of the vessel, oxygen gas was given out, and yellowish white muriat of potash was formed, but no oxymuriatic acid, nor was any light produced.

With carbonic acid gas the peroxyd when heated gave out oxygen gas, and carbonat of potash was produced which strongly effervesced with acids, but no water was generated.

The peroxyd was heated with sulphureous acid gas and the experiment was conducted with much care. The gas was carefully dried and had the specific gravity of 2.2553 (common air being 1.) the quantity of it as well as that of the peroxyd of potassium was weighed, as also was each of the products after the experiments. As soon as the heat was applied a brisk inflammation took place and an abundant absorption of gas. Sulphat of potash was formed, and a little oxygen gas, but not a trace of aqueous vapour. The oxygen was then separated from the undecomposed sulphureous acid, and the weights of the two gasses, added to that of the sulphat of potash, were found to equal that of the sulphureous acid gas and of the peroxyd of potassium employed.

The peroxyd was heated in nitrous gas, but without any particular estimation of quantities. Much absorption took place, very red nitrous acid gas appeared, and a salt was melted to the

* Davy.

* Gay Lussac, and Thenard.

bottom of the retort which was nitrite of potash. Nitrous oxyd produced no alteration whatever on the peroxyd of potassium.

The peroxyd may be made by heating potassium either in oxygen or in nitrous gas or in nitrous oxyd. In the latter cases, the potassium becomes highly oxydated at first, but on continuing the heat, seems to return to the state of alkali, and nitrite of potash is formed.

The French chemists, whose experiments we are now describing, consider the peroxyd of potassium as containing three times as much oxygen as the quantity necessary to convert potassium into potash; so that if potash consists of 84. parts by weight of potassium to 16 of oxygen, the peroxyd of potassium will consist of 84 of potassium to 48 of oxygen, or 63.64 per cent. of potassium and 36.36 of oxygen.

Potassium and Hydrogen. These combine neither at a common temperature nor at a red-heat, but readily at an intermediate degree, such as is produced by a spirit-lamp. Potassium thus heated in hydrogen gas absorbs it rapidly, but gives it out again with equal ease when the proper degree of heat is exceeded. The actual quantity of hydrogen absorbed seems to vary considerably, but on an average it appears to be about a fourth of the quantity which would be produced by immersing the potassium in water. This Hydruret of Potassium is grey, unmetallic in appearance and infusible. It inflames in common air or in oxygen only when heated. It is entirely decomposed into hydrogen and potassium when heated *per se* in a close vessel, and when in contact with hot mercury it is still more rapidly destroyed, the hydrogen flying off and the potassium amalgamating with the mercury.

Phosphorus unites readily with potassium. This compound is made by introducing the two into a glass tube filled with azotic gas and gently warming them. But little light is given out. The phosphuret of potassium has an unmetallic appearance, is of a chocolate colour, and when thrown into water produces phosphuretted hydrogen gas, which sometimes but not always inflames.

Sulphur forms a very intimate union with potassium, and the combination takes place with much more heat and light than in the phosphuret, so as to endanger the glass vessel, unless the sulphur and potassium are placed upon a platina dish within the tube, which last should be filled with azote. This sulphuret is sometimes yellow, sometimes red. It has the

smell and taste of rotten eggs, is soluble in water without the production of any gas, but with acids it is readily decomposed with evolution of sulphuretted hydrogen gas.

When potassium is melted in sulphuretted or phosphuretted hydrogen gas, a sulphuret or phosphuret of potassium is formed, and the hydrogen remains pure.

Alloys of Potassium and the Metals.

Potassium very readily unites with many of the metals, as was first ascertained by Davy, and indeed this circumstance is one that is brought forward as an argument of the metallic nature of this singular substance. Some of these alloys, as described by the discoverer, we have already mentioned; the following experiments are given by M. M. Gay Lussac and Thenard. The alloys were made either by heating the substances in a small bent glass tube over mercury and filled with azotic gas, or by introducing the potassium into a small glass tube closed at one end, covering it with the metal in powder, then drawing out the other end of the tube over a lamp and sealing it hermetically, and finally uniting the metal and potassium by a due heat over lighted charcoal.

Potassium 2 measures, lead in powder 8 measures, gave a solid brittle fusible fine-grained alloy. Exposed to air it decomposed gradually, and in water, suddenly. In either case potash was produced and the lead resumed its metallic state. Potassium 2 measures, bismuth 8 measures, a solid brittle alloy in small facets: decomposed as the last. Potassium 2 measures, antimony 8 measures: this mixture alloyed with great ease, giving out light in the process: decomposed as above.

Potassium 2 measures, tin 7 measures. Some light is given out during the union, which requires almost red heat to be effected. This alloy must be made in azotic gas as it is immediately decomposed in the air. When the tin is in a less proportion than the above, the alloy generally takes fire the moment it is attempted to be pulverized.

Potassium and zinc alloy with difficulty on account of the volatility of the potassium at the heat required.

Potassium and mercury will unite in any proportions. When the former was to the latter as 212 by weight to 3069, the amalgam remained fluid at a mean temperature. With twice the above quantity of potassium much heat was excited on mixture, and the amalgam was solid at a common temperature and easily

crystallized. The crystallized texture was still more decided with three portions of potassium. These amalgams will take place without heat when the potassium is free from oil or oxyd on its surface and quite clean. They often occur accidentally by the fall of particles of potassium on the mercury bath, which, as soon as they touch the mercury, move about on its surface with great rapidity, and soon disappear by being absorbed by the fluid metal. Much heat is given out when potassium and mercury unite.

Potassium 2 measures, arsenic 6 measures. This alloy is easily made and much light is given out at the time, but instead of having a metallic lustre it is of a dull chesnut brown hue, and when in contact with water it gives out a much smaller bulk of hydrogen gas than the same quantity of potassium gives when alloyed with any other metal. This gas was therefore examined with more care. A bent glass tube was filled with azote over mercury and 2 measures of potassium, and a piece of arsenic were introduced into the tube and united by fusion. The azotic gas was not in any degree altered. Water was then thrown up which caused a brisk effervescence and the production of potash, and the alloy was entirely destroyed, leaving only a light flocculent matter like kermes. The water was boiled to complete the decomposition of the arsenical alloy. The only gas produced was 82 measures of arsenicated hydrogen. This experiment was repeated many times with different proportions of potassium, the gas being always measured, and it was found to be pretty accurately in direct proportion to the quantity of potassium used: but it was also found that the same quantity of potassium which when unalloyed with arsenic gave 79 parts of pure hydrogen, would give only on the average 33.36 parts of arsenicated hydrogen. This led to the analysis of arsenicated hydrogen. This gas was prepared both by moistening the alloy of arsenic and potassium, and by adding muriatic acid to an alloy of 3 parts of tin and 1 of arsenic. A given quantity of this gas was confined in a glass vessel over mercury, in contact with a vessel containing tin which was kept in fusion for three quarters of an hour. This process extracted all the arsenic from the gas, which then returned to the state of simple hydrogen, as was determined by there being not the least deposition of arsenic on the sides of the vessel in which the gas was subsequently burned. From the result of several experiments which agreed

sufficiently well, it was shewn that 100 measures of arsenicated hydrogen expand to 140 parts after the extraction of the arsenic. But this circumstance would only account for part of the apparent deficiency in the quantity of gas produced by the action of water on the alloy of arsenic and potassium, for if 140 measures of pure hydrogen produce 100 measures of arsenicated hydrogen, 79 of hydrogen (the quantity produced by each measure of pure potassium) should give 56.4 of the arsenicated gas, whereas the quantity of the latter gas actually produced, was only 33.36. This therefore would imply some loss of hydrogen, or rather a condensation of it in some one or other of the products so as to prevent it from assuming a gaseous form, and this the authors with great probability suppose to be the case in the brown arsenical flocculi that remain after the action of water upon the arsenical alloy, which flocculent matter therefore will then be a *Hydruret of Arsenic*. The possibility of a solid compound of hydrogen and arsenic has also been inferred by Sir H. Davy, as a result of the following experiments on the action of tellurium and arsenic on potassium.^d Arsenic being made the negative surface in a powerful galvanic action taken in water, became dark coloured and threw down a brown powder, at the same time giving off much inflammable gas. Also an alloy of arsenic and potassium being heated in ammonia produced a gas which was principally azote, and hence the hydrogen of the decomposed ammonia must have entered into combination with the arseniuret of potassium.

Potassium heated in arsenicated hydrogen (to return to M. M. Gay Lussac and Thenard) becomes immediately covered with a red crust, dense fumes condense on the sides of the vessel, the gas is suddenly decomposed, and therefore expanded, pure hydrogen appears, and the arsenic combines with the potassium into a solid arseniuret similar to that produced by the direct union of arsenic and potassium.

Potassium may be readily alloyed with iron by putting some iron turnings in the lower extremity of the gun-barrel that projects beyond the furnace (in the apparatus for obtaining potassium) instead of leaving it empty to receive the condensed potassium. In this case the iron being long in contact with potassium in vapour absorbs it, becomes flexible, and often quite soft, and is decomposable in air or water like any of the other alloys of this substance. With-

^d Phil. Trans. for 1810, p. 27, &c.

out doubt the alloys of the other metals that require a high heat for their fusion might be obtained in this way.

Potassium and Gaseous Oxyd of Carbon have no mutual action at a common temperature, but when heated they readily decompose each other. About 200 measures of carbonic oxyd (obtained from iron filings and carbonat of barytes previously ignited strongly) were heated with a portion of potassium. On the first impression of heat the potassium became blue, but presently took fire, a great and immediate absorption of gas took place, carbon was precipitated, almost all the potassium was changed to potash and the whole gas disappeared except about twelve measures, which were afterwards decomposed in a similar manner by a fresh portion of potassium.

Potassium and Metallic Oxyds. It has been already mentioned that the celebrated discoverer of the alkaline bases ascertained the extreme affinity of potassium for oxygen in every combination, which therefore renders it a most valuable re-agent for an infinite variety of chemical purposes. Among these he discovered that many and probably all the metallic oxyds when heated with potassium, are reduced to the metallic state by yielding their oxygen to the potassium; and if the latter is in excess, the newly reduced metals will alloy with this excess, or will unite with the potash newly formed in case the metals are soluble in this alkali.

Similar experiments have been repeated by the above French chemists on a great variety of metals, and with the same general results. They were all performed in a small glass tube, one end open, the other closed. A layer of the metallic oxyd was first put in, and over it the potassium, well cleaned from oil by blotting paper, and upon this another layer of the oxyd. The tube was then heated over a fire as required. In almost all the cases the reduction of the oxyd was attended with light, and generally the potassium passed to the state of potash, and not to that of either of its other oxyds.

The particulars of these experiments need not be specified in this place.

Potassium and the Mineral Acids. Carbonic acid gas and potassium do not act upon each other at a common temperature, but at a heat approaching a cherry-red, the decomposition is rapid and compleat. The approach to this is shewn by the potassium becoming blue. It then takes fire, and the gas is ab-

sorbed almost entirely, leaving a little residue of carbonic oxyd, and an abundance of carbon precipitates. The potash thus generated is partly carbonated.

Potassium and sulphureous acid act on each other when heated, the gas is almost totally absorbed if the potassium be in sufficient quantity, and the solid residue is sulphuret of potash.

In nitrous acid gas potassium inflames even at an ordinary temperature, and burns with a red flame.

With oxymuriatic acid gas the appearances are nearly similar. The potassium burns with a red flame, and muriat of potash is produced.

When potassium is heated with muriatic acid gas, hydrogen is disengaged, and solid muriat of potash results. The quantity of hydrogen is the same as would be given out by the action of water on the potassium, and it is half that of the muriatic acid absorbed.

Vitreous phosphoric acid heated with potassium produces a pretty strong combustion, and red phosphuret of potash is left, which when wetted gives phosphuretted hydrogen not inflammable by exposure to air.

Potassium and Alkaline, Earthy, and Metallic Salts. The action of these substances was ascertained in the same manner as that of potassium on the metallic oxyds.

In all cases the potassium abstracted oxygen from those salts which are known to contain it, and the potassium was generally changed into potash, and not into either of its other oxyds. In many instances light was disengaged at the moment of mutual action. The salts employed were all previously dried as much as possible.

The sulphats heated with potassium were more or less perfectly converted into sulphurets.

The phosphats were in like manner changed to phosphurets, giving when moistened that species of phosphuretted hydrogen which is not spontaneously inflammable.

The carbonats with potassium were decomposed into carbonic oxyd, the base of the carbonat employed, and potash from the potassium.

Muriat of barytes and muriat of soda were not altered by potassium, which sublimed through them, being itself unchanged.

The fluats of soda and lime were equally unaltered.

Borax was unaltered by potassium.

SODIUM.

This substance was discovered by Sir H. Davy a few days after the discovery of potas-

sium, and by the same means, that is, by the electro-chemical action of a powerful galvanic battery acting on solid caustic hydrat of soda. The mode of preparing sodium therefore is precisely the same as that of potassium, substituting one alkali for the other. Sodium may also be readily prepared by igniting common salt and then heating it to redness with potassium in a close vessel. The salt is immediately decomposed, and the sodium rises very pure. No hydrogen is disengaged in this process, and two parts of potassium produce rather more than one of sodium.*

Sodium is also prepared by the process discovered by Messrs. Gay Lussac and Thenard, for obtaining potassium, the apparatus being precisely similar, and no other difference being required than to substitute soda for potash as the alkali to be passed through the ignited iron turnings. As solid hydrat of soda contains much more water of composition than hydrat of potash, it should be kept for some time in fusion at a low red heat just before it is put into the gun barrel apparatus. In the distillation, a still greater heat is required to obtain sodium than potassium, and the transmission of the soda through the heated barrel should be slower.

Pure sodium is an opaque substance with a white silvery lustre. It melts at about 200° Fahr. if unalloyed with potassium, and it rises in vapour at a strong red heat. It is exceedingly malleable and soft like wax so as readily to be pressed out into thin leaves. Portions of sodium may easily be united into one mass by strong pressure, a species of *cold welding*. Sodium is a very powerful conductor of electricity. Small globules of it inflame by the Voltaic spark, and burn with bright explosions. The specific gravity is given by Davy at 0.9348 (water being 1.0) and by the French chemists at 0.97223.

Before we describe the chemical properties of sodium we shall notice its alloy with potassium, as this very materially alters its fusibility and specific gravity. These two substances unite perfectly, and indeed the alloy is always produced whenever the soda employed for the production of sodium is mixed with any portion of potash. This is the case with all the common soda or carbonat of soda that is used when prepared from barilla, unless particular pains be taken to purify it by repeated solution and crystallization; so that where sodium is to be obtained directly from the de-

composition of soda, the alkali manufactured from common salt is perhaps the surest.

When the soda contains as little as five or six per cent. of potash the mixed alkaline metal thence obtained becomes fluid at a temperature little above that at which pure potassium melts, and when the alloy contains more potassium it remains fluid at a common temperature. Three parts of sodium and one of potassium from an alloy fluid at 30°, and which crystallizes into a bright brittle mass when surrounded by salt and ice. Even a thirtieth part of potassium in the alloy materially encreases its fusibility.

An alloy of 10. parts of potassium and 1. of sodium is also fluid at 32°, and is lighter than rectified naphtha. These alloys therefore are in all cases more fusible than pure sodium, and often more so than pure potassium, and they are also always brittle and crystallizable. The alloys may be made either by heating the alkaline metals under naphtha, or even by simple pressure without heat. It should be observed that these alloys are gradually oxydated even under naphtha when exposed for some time to the air, and that it is the potassium which first undergoes this change, and by this means sodium may be purified from a small admixture of potassium, the latter being entirely oxydated before the former is altered.

When sodium is exposed to the atmosphere it immediately tarnishes and gradually becomes covered with a crust of soda which deliquesces. Sodium confined in oxygen gas combines with it slowly and without any luminous appearance at a common temperature, but when heated it burns with a very white brilliant sparkling flame. In common air the flame is yellow.

When sodium is thrown on water it produces a violent effervescence of hydrogen with a hissing noise, the globules run about in all directions on the surface of the water, rapidly lessen without flame or explosion, and gradually disappear, leaving the water alkaline by the soda produced. The quantity of hydrogen produced by a given weight of sodium in water is thus given by Messrs. Gay Lussac and Thenard, whose experiments very closely coincide with the results adopted by Sir H. Davy. The mode of conducting the experiment was exactly the same as with potassium. 2486 grammes of sodium decomposed by water gave 1.2525 litres of hydrogen gas at 15° centigrade Th. and 0.759 metre Bar.; whence it follows that 100. parts

* Davy.

by weight of sodium absorb 33.995 parts of oxygen during its conversion into soda, and therefore 100. parts of pure soda free from all water of composition, contain 74.63 of sodium and 25.37 of oxygen.

The numbers adopted by Davy^b are 88 of sodium to 30 of oxygen (88 being the number representing one proportion of sodium) which would give 74.5 per cent. of sodium and 25.5 of oxygen.

Oxyds of Sodium. The oxydation of sodium seems in every respect to run a parallel course with that of potassium.

There are three oxyds of sodium known, of which the alkali soda is in the intermediate degree of oxydation.

The suboxyd of sodium is formed like that of potassium by very slow circulation of air in a vessel confined by a cork. This suboxyd is grey, brittle, unmetallic in appearance, and gives out some hydrogen when moistened, but less than sodium.

The pure alkali Soda, free from water of composition forms the next oxyd of sodium. Its composition has just been mentioned. It is formed, like the pure potash, by heating the peroxyd. When produced by the action of water on sodium it always retains a considerable portion of water which is not expelled even at a red heat.

The peroxyd of sodium is formed as the peroxyd of potassium by heating the alkaline basis in oxygen gas. Its natural colour is a dirty yellow; but brown when prepared upon uncovered platina. When thrown into water it is immediately decomposed and passes to the state of alkali, giving out oxygen gas.

The experiments made by the French chemists to find the utmost quantity of oxygen gas absorbed by the combustion of sodium, in no degree accord with each other, except to shew that the term of oxygenation that produces the alkali is pretty accurately defined.

But beyond this, the excess of oxygen absorbed to produce the peroxyd (and which excess is given out when water is added) varies so much in the experiments given that no accurate inference can be made. The utmost quantity of this excess is somewhat more than half the quantity of oxygen absorbed to produce the alkali, and this proportion is also given by Sir H. Davy. Hence it may perhaps be allowed that sodium with two portions of oxygen becomes soda, and with three portions the peroxyd.^c We may add that a very considerable

error has crept into the calculations of these eminent chemists from their own data. The quantity of oxygen absorbed by one measure of sodium is *not* 148 of the measures used, but half this number, or 74. It is the hydrogen given out which is 148, and hence the oxygen absorbed would be half this quantity *in bulk*, or 74; and this too agrees with the other numbers of the table given, being pretty nearly the quantity left after the action of water on the peroxyd in all the five experiments.

The chemical properties of sodium and its oxyds so closely resemble those of potassium in parallel cases as to render a particular description unnecessary. In almost every instance sodium absorbs oxygen from every substance containing it (the oxyds of potassium excepted) and the peroxyd yields that excess of oxygen above the quantity necessary for alkalization to almost every substance which has an affinity for oxygen.

Oxygenation of the common caustic alkalies by fusion. After the discovery of the peroxyds of potassium and sodium it was natural to examine whether any process of superoxygenation of the alkalies in their common state (that is as *Hydrats*) ever took place, when they were kept in fusion at a red heat exposed to the atmosphere. At a common temperature it is obvious that the deliquescence of these alkalies would of itself prevent any higher degree of oxygenation; and as even at a red heat the water of composition entering into these alkalies is not driven off, it was doubtful whether this circumstance might not oppose the further absorption of oxygen. Messrs. Gay Lussac and Thenard however assert that when common caustic potash or soda, prepared by alcohol, is kept in fusion at a red heat in an open crucible of silver platina or earth, it absorbs oxygen and partly passes to the state of peroxyd, and will again give out oxygen gas on being dissolved in water. A silver crucible answers best as the alkali has no action on it. Potash oxydates sooner under these circumstances than soda, so that in eight or ten minutes of fusion its colour deepens and it gives out much oxygen when wetted. But when the alkali is combined with carbonic acid no such superoxygenation takes place by any length of fusion.

On the other hand they assert that the nitrats of these alkalies when thrown into a red hot crucible and kept long enough to be compleatly decomposed, very readily furnish the peroxyds of the alkaline bases.

^b Elements.

^c See Recherches, &c. par MM. Gay Lussac and Thenard, tom. i. p. 513.

ALLANITE.*

This mineral occurs in oblique tetrahedral prisms, the alternate angles of which measure 117° and 63° , or in compressed hexahedral prisms terminated by tetrahedral summits; it also occurs uncrystallized and then is either massive or disseminated being mixed with black mica and felspar. Its specific gravity as far as can be ascertained on account of the intimately intermixed mica, is between 3.1 and 4.0. Its colour is brownish-black; when bruised dark greenish grey. Externally it is dull. Internally it exhibits a small conchoidal fracture with a shining lustre between resinous and metallic. It is opaque, in hardness ranks between felspar and glass; is brittle and easily frangible. Before the blow-pipe it froths and melts into a brown slag. It gelatinizes in nitric acid, and loses about 4 per cent. of its weight by strong ignition.

The substances obtained from 100 parts of it on analysis by Dr. Thomson, are

35.4	silica
9.2	lime
4.1	alumina
25.4	per-oxide of iron
33.9	oxide of cerium
4.0	volatile matter

112.0

Allanite is a native of Greenland, but of its geological history we are as yet entirely ignorant.

ALLOCHROITE.^b Splittiger Granat K.

The colour of this mineral is yellowish or brownish-grey. It occurs in opaque amorphous masses. Its fracture is uneven passing to splintery, with a slight degree of lustre. It gives sparks with steel, and is difficultly frangible. Sp. gr. 3.5. Before the blow-pipe it is fusible without addition into a black shining opaque enamel.

It has been analysed both by Vauquelin and Rose, with the following results;

V.		R.	
35.	—	37.	silica
30.5	—	30.	lime
8.	—	5.	alumina
17.	—	18.5	oxide of iron
3.5	—	6.25	oxide of manganese
6.	—	0.	carbonate of lime
100.0		96.75	

This mineral is considered by Karsten as a variety of garnet, and in fact its analysis nearly coincides with that of melanite or black garnet.

It occurs generally in pieces covered by carbonate of lime, and by dodecahedral crystals which appear to be garnet. These dodecahedrons are implanted by their lower extremities in the allochroite, into the substance of which they appear to pass by insensible degrees. The carbonate of lime in Vauquelin's analysis is no doubt foreign to the composition of this mineral and is to be attributed to the calcareous spar with which it is mixed.

It occurs in the iron mine of Virums, near Drammen in Norway.

ALOE.

Three analyses have been made of this substance, of which the following is an abstract.

The first we shall mention is that of M. Braconnot.^c

Aloes is a dark brown semi-transparent extract, easily reduced to powder, and very bitter, prepared from the natural juice of several species of the aloe plant, either by natural or artificial heat. The finest species is prepared only by inspissation in the sun's heat. The finest sort was selected for the following experiments:

50 grammes were heated *per se* in a retort, with a heat at first very gentle, and afterwards increased. The first product was a water loaded with the flavour of aloes, then a colourless water holding some acetous acid but no ammonia: then a red oil soluble in alcohol; and then at a higher heat much carburetted hydrogen with oil. The coal contained no potash.

Aloes rubbed in a mortar with water produces a viscous mass like turpentine when pressed with the fingers. A large quantity of water however dissolves the whole, excepting a little woody impurity, and the solution of the last portion is as bitter as the first. By heating the water, the solubility of aloes is greatly increased, and the hot saturated solution will assume somewhat of a crystalline form by cooling. The watery solution of aloes reddens litmus. Its colour is rendered deeper by lime-water and the alkalies, but nothing is precipitated. Goulard's extract produces a deep precipitate, and the supernatant liquor becomes colourless.

The watery solution when long exposed to the air becomes mouldy, and then gives an abundant precipitate with gall-nut, but when

* Nich. Journ. xxix. 48.

^b Haüy Tab. Comp. 57.

^c An. Chim. Tom. 68.

the solution is recent this reagent only slightly disturbs it.

Spirit of wine dissolves aloes with great ease when warm. The solution is of a very deep red, and water added to it gives a copious pale yellow sediment. If the spirituous solution is much lessened by evaporation, the slightest agitation causes the surface to assume a crystalline form.

Neither the fixed nor the essential oils dissolve any sensible portion of aloes.

All the alkalies dissolve aloes very easily even without heat, and the intense bitter is somewhat corrected in this solution.

The ammoniacal solution carefully evaporated almost to dryness, gave the author a number of needled crystals impacted in a resiniform mass. These crystals gave the smell of ammonia when rubbed with lime and moistened, and hence this alkali appears to be one of their component parts.

Weak acids merely dissolve aloes, and somewhat more abundantly than water does.

Nitric acid dissolves it easily in the cold, producing a blood-red liquid, precipitable by water. A quantity of aloes was put into a retort and heated cautiously with eight parts of strong nitric acid. Abundance of nitrous gas was given out, and when this action had ceased the retort contained a yellow liquid, which on cooling deposited a good deal of a yellow flocculent substance, that weighed after washing on the filter about a quarter of the weight of the aloes employed. The author considers this as an acid possessing some peculiar properties, and terms it the *Aloetic Acid*. It is of a very fine yellow and intensely bitter, not crystallizable, reddens litmus, and effervesces with the alkaline carbonates. Its smell is agreeably aromatic when warmed. It is very slightly soluble in water, and the solution has the colour of arterial blood. Alcohol dissolves only $\frac{1}{10}$ of its weight of this acid. The mineral acids merely dissolve without decomposing it. Potash forms a red crystallizable salt with this acid, which detonates with the violence of gunpowder when heated sufficiently or touched with an ignited body. The salt is easily produced by pouring a weak solution of caustic potash on the yellow aloetic acid.

The liquor that remains after the extraction of this acid from the heated mixture of aloes and nitric acid, contains also much oxalic acid, so as to give a copious precipitate of oxalate of lime on the addition of nitrat of lime.

* An. Ch. tom. 68.

M. Braconnot infers from his experiments, that the chief constituent part of aloes is neither a gum nor resin, but a substance *sui generis*, which he terms *Bitter Resin* (*Resino-Amer.*)

M. Trommsdorff has given a comparative analysis of the Socotrine and Hepatic aloes,^d of which a few particulars may be mentioned. Four ounces of aloes were boiled with 3 pints of distilled water. The whole dissolved, but became very turbid on cooling, and a yellow substance separated, weighing an ounce after drying. This substance was a bitter, yellow, brittle, transparent resin, fusible at a gentle heat, insoluble in water, very soluble in alcohol and potash, and highly inflammable.

The liquor that contained that part of the aloes which remained soluble in water, was evaporated to dryness, and gave a brown bitter mass equally soluble in water and alcohol, but insoluble in ether, which the author considers as identical with what Hermbstaedt terms the *Saponaceous Principle* of vegetables. Another portion of aloes was analyzed by first digesting it in alcohol, in which it totally dissolved without any residue but a few grains of woody impurity. The solution remained clear after cooling. After being evaporated to dryness, the residue was digested with water, and only three fourths of it dissolved, leaving one fourth of resin; which confirmed the general proportion of resin and other matter found in the first experiment.

Some difference was found in the subsequent analysis of the *Hepatic* aloes, this species containing about $\frac{1}{10}$ th of albumen which resisted solution in boiling water and in alcohol, owing to its coagulation. This therefore is given as a mode of distinguishing the two species; the Socotrine aloes dissolves entirely in boiling water and in alcohol, but the Hepatic when thus treated, leaves a portion of coagulated albumen.

Further experiments have been made upon aloes by Messrs. B. La Grange and Vogel,^e with some slight difference as to results.

A portion of each kind of aloes was distilled *per se*. Some water and oil passed over, the former of which gave a brownish-black colour to sulphate of iron, but this tinge did not resemble that produced by the distilled water of the gall nut; neither was the water of the aloes at all altered in colour by lime, barytic or strontian-water, all of which give a blue, green, or rose-colour precipitate with these

* An. Ch. tom. 68.

reagents. Hence the authors conclude that aloes contains no gallic acid. The distilled water of the hepatic aloes gave a sensible quantity of ammonia.

A second distillation of each species of aloes was made with the addition of water in the retort. The socotrine aloes gave a pleasant sweet-smelling water, not acid, on which floated a greenish yellow oil smelling like melilot. The distilled water of the hepatic aloes on the other hand was nauseous, and no oil separated.

The action of cold water on aloes was somewhat different from that observed by M. Braconnot. The latter chemist asserts that cold water in sufficient quantity will dissolve the whole of the aloes, and that the last dissolved portion equals the first in bitterness. On the other hand, the authors of the present paper found that by digesting the aloes with successive portions of cold water, and pouring off the liquors after remaining for some hours in contact till nothing more was extracted, there remained a soft grey elastic mass insoluble in water, resembling a resin. The watery solution is thick and lathers much on agitation. It deposits a yellow powder on the addition of a great variety of substances, such as all the mineral acids, all the neutral, and a great many of the metallic salts. Those of iron produce a brown precipitate, but different from that given by galls. All these precipitates from the aloetic solution are soluble in water. The watery solution, evaporated slowly to dryness, leaves a brown transparent vitriform mass intensely bitter, and perfectly soluble in water and alcohol, but very sparingly in ether.

On the other hand the resinous matter of aloes is not soluble in cold water, but dissolves in alcohol and ether, and the latter solution is abundantly precipitated by water.

The action of nitric acid observed by these chemists was nearly the same as that described by M. Braconnot. The yellow powder produced by heating aloes in this acid, gives a most beautiful purple colour to a large quantity of water. When this powder is gently heated *per se* in a retort, as soon as it melts, it explodes slightly, and an acid yellow bitter liquor passes into the receiver, smelling of prussic acid and evolving ammonia on the addition of potash.

Oxymuriatic acid passed through a concentrated watery solution of aloes is absorbed in great quantity, the liquor becomes yellow and coagulates strongly so as almost entirely to solidify. This coagulum when washed is elastic,

insoluble in cold water, but abundantly soluble in alcohol, which solution is copiously precipitated by water. The action of oxymuriatic acid therefore appears to convert much of the aloes into a perfect resin.

ALUM.

§ 1. *Ores and Manufacture of.*

The largest alum mine in Britain is at Hurlitt near Glasgow.^a In the colliery at that place is a bed of coal about five feet thick covered by a roof of pyritical slaty clay of the thickness of ten inches. The coal with the superincumbent roof dips just enough to afford a free passage for the water, and the mine is worked, contrary to the usual practice, from the rise to the dip; hence all the workings are necessarily kept perfectly dry. For three centuries has this colliery been in work, and it now presents an excavation the area of which is nearly a mile square, with pillars of coal at the usual intervals in order to support the overlying beds, the thickness of which is on an average about 30 fathoms. The air circulates slowly through the whole of this space by means of such of the old shafts as still remain open; and, in consequence, a slow decomposition of the roof is perpetually going on. This process however is so gradual that in no part has the slate been hitherto entirely removed.

The first action of the air is to cause a thin flake to scale off from the roof and fall upon the dry floor; in this last situation the decomposition makes further progress, and by degrees assumes the appearance of a light spicular efflorescence. Succeeding flakes go through a similar process, and in time the whole space up to the very roof itself is completely filled; the current of air being then obstructed, all further decomposition of course ceases till the effloresced portion is removed.

The mass thus obtained consists of earth richly impregnated with sulphate of alumine, sulphate of iron, and in some cases with sulphate of magnesia. The salts are separated by lixiviation from the insoluble residue, the sulphate of alumine is converted into alum by the addition of sulphate or muriate of potash, and the manufacture is finished in the usual way.

The oldest alum works in this country are at Whitby in Yorkshire,^b where there occurs a vast deposit of alum slate about twenty-nine miles broad from N. to S. and stretching from the eastern coast even into Lancashire. The depth of this mass is unknown, but it is covered

^a Ph. Journ. xvi. p. 233.

^b Ph. Journ. xxv. p. 241.

by alluvial soil, by sandstone lying upon or sometimes inclosing a thin bed of coal, by ironstone, shale and clay.

The alum slate itself, although tender near the surface, is at the depth of about 100 feet equal in hardness and compactness to common roof-slate. The upper part, whether from being actually richer in pyrites, or in a state of partial decomposition, is found to yield four or five times as much alum as the lower part, this latter being at the same time considerably more bituminous. Ammonites, nautilites, and trochites, together with belemnites, abound in the schistus; vertebræ and other bones of amphibious animals are also met with. Wood converted by bituminization into a more or less perfect jet is of not unfrequent occurrence, and several subordinate beds of red iron ore are worked at the depth of about 200 feet.

The alum slate being procured by means of the pickaxe, the first process to which it is subjected is roasting. For this purpose a bed of faggots and brushwood four or five yards broad and two yards high is covered to the height of about four feet with the ore broken very small; it is then kindled, and fresh ore is continually added; the breadth of the pile is also increased by successive additions of faggots and ore till at length the mass reaches the height of 80 or 100 feet, covering an area 150 or 200 feet square, and containing about 100,000 cubic yards of ore. The combustion is moderated by covering the surface with the more earthy part of the ore, and after a time it is extinguished spontaneously.

Of this calcined mine it takes on an average 130 tons to produce one ton of alum. For this purpose the ore is steeped in pits containing about 60 cubic yards at a time, and the solution (technically called alum liquor) is drawn off into a cistern, from which it is again pumped upon fresh calcined mine. This process is repeated till the liquor acquires a specific gravity of 1.15. The ore after having been once steeped is lixiviated again a second and third time, and these weaker solutions are used instead of water in subsequent steepings.

The strong liquor is drawn off into cisterns where it deposits much selenite and oxyd of iron; it is then boiled for a short time and allowed to cool, by which nearly the whole of the grosser impurities are got rid of. The liquor thus clarified is transferred to a leaden boiler, where it is mixed with a quantity of mother liquor and kept briskly boiling during the whole

day, the loss from evaporation being from time to time supplied by fresh liquor. The concentrated solution from the whole of the pans is run every morning into a vessel called a settler, where its specific gravity is taken, and is generally found to vary between 1.45 and 1.5: a solution of crystallized muriate of potash is then added, sufficient to lower the specific gravity to 1.35, and the whole is carefully mixed together. The liquor then stands in the settler about two hours in order to deposit the sediment which it contains, and when clear is transferred into the coolers to crystallize. After standing four days the mother liquor is drained off, and the crystals of alum washed with water in a tub, whence they are conveyed to a bin with holes in the bottom that the moisture may run off. The washed alum is then put into a large leaden pan with as much water as is requisite to hold the salt in solution at a boiling heat; the solution being complete the hot liquor is immediately run into casks. Here it remains about sixteen days; at the end of which time the casks are taken to pieces in order to get out the hollow mass of alum entire; this latter is then pierced, the mother liquor is let out and the alum itself being cleared from any adhering dirt is broken into pieces of about 1 cwt. each, and is ready for sale.

150 tons of calcined mine afford 1 ton of alum.

The daily produce of each pan is about 4 cwt. of alum, for which about 18 bushels of coal are required.

22 tons of muriate of potash are necessary for every 100 tons of alum.

§ 2. *Analysis of Alum.*

The most accurate analysis of alum is by Vauquelin^a; in his comparative examination of several varieties of this salt, for the purpose of ascertaining whether there is any such real superiority of the Roman alum, and of certain other foreign varieties of the same substance, over the French manufactures of this article as it seems, is generally supposed by the French dyers and calico-printers. The four most interesting varieties out of the six which were analysed by this able chemist, were the following: 1. Genuine Roman alum. 2. Ditto from a manufacture at Liege. 3. Ditto English. 4. Ditto French from the manufacture of M. Ribaucourt.

The method pursued was to dissolve the alum in water, and by the addition of ammonia in excess to separate the alumine and oxide of iron, the precipitate being perfectly well

^a Ann. Chim. l. p. 154.

washed was dried and finally ignited in a platina crucible. A fresh portion of alum was then taken and decomposed by muriatic acid for the purpose of ascertaining the amount of sulphuric acid from the sulphate of barytes produced. The ammoniacal liquor in the first process was evaporated to dryness, the residual salt was ignited in order to drive off the sulphate of ammonia, and the remainder was sulphate of potash. A fresh portion was boiled in a retort with caustic potash, and the ammoniacal liquor which came over was saturated

with sulphuric acid and then evaporated; the remaining sulphate of ammonia indicated the amount of volatile alkali contained in the alum. Lastly, the alumine obtained in the first process was digested in caustic potash till the whole of the earth was taken up, and thus separated from the oxide of iron which is insoluble in this menstruum. From analyses carried on in the manner just mentioned it appears that the following are the component parts of the four varieties of alum examined by M. Vauquelin, viz.

Roman	—	Liege	—	English	—	French	
10.36	—	10.39	—	10.21	—	10.16	Alumine
31.82	—	31.49	—	31.64	—	31.49	Sulphuric acid
12.17	—	12.17	—	12.20	—	12.45	Potash
0.	—	0.29	—	0.47	—	0.41	Ammonia
0.	—	0.098	—	0.246	—	0.262	Oxyde of Iron
54.35	—	54.488	—	54.766	—	54.772	

What remains to be added to each, that the original 100 parts may be complete, is water of crystallization.

Hence it appears that the sole difference between the most and the least valued kinds of alum is that the latter contains a few thousandths of the sulphates of ammonia and of iron, which are wholly or almost wholly wanting in the former. It became therefore a matter of importance to ascertain by direct experiment the effect of a small portion of these salts upon the more delicate dyes, and in consequence an investigation to this purpose was undertaken by M. M. Thenard and Roard.^a

The result of their inquiry has been, that in dyeing *wool* with the most delicate colours, such as weld, cochineal, sumach, madder and kermes, the use of Roman instead of common alum is of little or no consequence; that the colours of *cotton* are sensibly deteriorated by the employment of impure alum, and that this effect is still more sensible in the dyeing of *silk*. Sulphate of ammonia even in much larger doses than it exists in the most impure alums is very little injurious, it is therefore the sulphate of iron that produces all the mischief.

Having thus ascertained that the preference given to the Roman over every other kind of alum in the market is by no means a prejudice, but founded on very substantial reasons, M. M. Thenard and Roard proceed to show that it is very easy to get rid of the sulphate of iron, and thus to raise the most impure alums completely to the standard of the Roman. For this purpose the alum is to be dissolved in as small a

quantity as possible of boiling water, and the solution while cooling is to be incessantly stirred; by this means the alum will be obtained nearly in a pulverulent state; it is then to be carefully washed two or three times in small portions of fresh water, and the purification is complete. [For the experiments of Thenard and Roard on the action of alum on colouring matter, see the article *DYING* in this Appendix.]

ALUMINUM.

The metallic basis of alumine has not yet been obtained in a free state, though sufficient indications of its existence have been made out by Sir H. Davy.^a When iron is negatively electrified with a high galvanic power and fused in contact with moistened alumine, a globule is obtained whiter than pure iron, which slowly effervesces in water and becomes gradually covered with white powder; and the solution in muriatic acid decomposed by an alkali gives alumine and oxyd of iron. Also when potassium is vaporized by heat, and in this state passed through alumine heated to whiteness, much potash is formed which produces a coherent mass with the undecomposed alumine, in which are found numerous grey particles which become white when heated in the air, and slowly effervesce in water. These grey particles appear to be an alloy of potassium and aluminum.

AMMONIA. AMMONIUM.

The following practical remarks on the preparation of the liquid ammonia may be

^a Ann. Chim. lix. p. 58.

^a Elements of Chemistry.

useful. Mr. Phillips has the following experiment.^a To 9 oz. of lime slacked with half a pint of water, and put in a closed vessel, were added 12 oz. of muriat of ammonia, and $3\frac{1}{2}$ pints of boiling water. The mixture having cooled, the clear solution was divided into two equal portions and separately distilled, without putting any water in the receiver or employing pressure. Ten ounce measures of distilled liquor of ammonia were obtained from each portion, of the specific gravity of .954, which according to Davy's tables indicates about $11\frac{1}{2}$ per cent. in weight of the pure alkali. The quantity of lime here used is amply sufficient, indeed the same weight as the muriat of ammonia would be sufficient, if the lime is made from marble or any pure limestone, and thoroughly well burnt.

Mr. Dalton^b has given a table of the strength of ammoniacal solutions somewhat differing from that of Davy. The data which Mr. Dalton assumes, (from particulars which need not be here enlarged upon) and on which the accuracy of the table depends, are the following:

100. water-grain measures of liquid muriatic acid of 1.074 sp. gr. contain 11. grains of real acid: the specific gravities of muriatic acid gas and ammoniacal gas are in the respective proportions of 1.23 and 0.6 and 11. measures of the acid gas saturated 12. measures of the ammoniacal gas. No allowance is required for condensation in constructing the following table, it having been found both by Davy and Mr. Dalton, that when liquid ammonia is mixed with water, the specific gravity is as nearly as possible the mean of the two. Mr. Dalton's table is the following.

Specific gravity.	Grains of ammonia in 100 water-grain measures of liquid.	Grains of ammonia in 100 grains of the liquid.
.85	30.	35.3
.86	28.	32.6
.87	26.	29.9
.88	24.	27.3
.89	22.	24.7
.90	20.	22.2
.91	18.	19.8
.92	16.	17.4
.93	14.	15.1
.94	12.	12.8
.95	10.	10.5
.96	8.	8.3
.97	6.	6.2
.98	4.	4.1
.99	2.	2.0

Analysis of Ammonia.

In the article *Ammonia* (Chem. Dict.) we mentioned the experiments of Priestley, Berthollet, and other chemists, which shewed this alkali to consist of azote and hydrogen, in the proportions of about 4 parts by weight of the former, and 1 part of the latter. A number of important researches have since been made by several eminent chemists, which require a detailed notice.

The fixed alkalies being proved by Davy to be compounds of a peculiar metallic base and oxygen, it naturally occurred to this eminent philosopher that the analogy with the other alkalies would infer a similar composition in the volatile alkali, which however seemed to be contradicted by the experiments of Berthollet and Sir H. Davy himself, in which ammonia was wholly resolved into azote and hydrogen, unless either of these latter substances was itself an oxyd of some unknown base.

A very laborious series of experiments on the analysis of ammonia by electricity and combustion with oxygen and other gasses, has been published by Dr. Henry,^c which we shall detail somewhat at large, on account of the great importance of the subject, the admirable practical skill and ingenuity with which the experiments were carried on, and the clear idea which it gives of the extreme difficulty which exists in obtaining perfectly accurate results in these delicate operations, from a variety of causes that are here explained.

The first object is the apparatus. Dr. H. found in former experiments that in the usual way of electrizing gasses, a temporary communication is made with the atmosphere at the moment of the explosion, which in the course of a long experiment is sufficient to introduce so much atmospherical air, as sensibly to affect the result. The only unobjectionable way, as Dr. H. mentions, is to inclose and hermetically seal the explosion wires in glass tubes, and then to grind away so much of the glass as will expose the ends of the wires. Those employed in these experiments were of platina, $\frac{1}{50}$ of an inch in diameter.

The next and most difficult object is to free the ammoniacal gas entirely from water. The avidity with which this gas retains moisture is very remarkable. A confined quantity of common air may be so completely desiccated in a few minutes by pure dry potash or dry muriat of lime, that no ice shall appear on the

^a Examinat. of the Pharm. Lond. 1811.
VOL. III.

^b New System of Chemical Philosophy, vol. 2d.

^c Philos. Trans. for 1809:

surface of the vessel when exposed to a cold of -26° . But ammonia requires exposure during some hours to potash to stand the test even of the temperature of 0. and a single transfer of the dried gas through mercury in ordinary use, again communicates moisture to it. The gas employed in these experiments was dried by sticks of pure potash fastened to steel wire, so that they could be withdrawn through the confining mercury when their drying action had ceased, and this was ascertained by applying ether or salt and snow to the outside of the glass. In some of the first experiments Dr. H. found that though the gas thus prepared deposited no moisture by cold before electrization, yet it gave a sensible quantity afterwards; but on applying heat just before the experiment both to the mercury and the iron cistern containing it, this condensation of moisture after electrization no longer appeared; at least only in the slightest possible degree; so that it seems necessary for perfect accuracy to heat the mercury and vessels as well as to dry the gas, and even to boil the mercury in the tube before admitting the ammonia.

With these precautions given quantities of ammonia were subjected to long continued electrization, by which (as already mentioned in our former article) the bulk of the gas is nearly doubled, and when no further increase takes place, the residue has now lost its alkaline properties, and is entirely resolvable into azote and hydrogen. Dr. Henry found from the mean of six experiments that 100 measures of pure ammoniacal gas were resolved by electricity into 198.78 measures of the mixed gasses, but the results of the experiment on which he placed the most confidence, on account of the scrupulous precautions observed against the intrusion of moisture, gave an increase of only 180.6 from 109 of ammonia.

The proportion of the hydrogen and azote to each other was ascertained by passing into the mixture a known quantity of oxygen gas, firing it with the electric spark, and estimating the hydrogen thus consumed, the azote being unaltered and constituting the chief part of the residue. In making this estimation, two measures of hydrogen are reckoned as saturating one measure of oxygen for the composition of water. Even this part of the experiment is liable to some inaccuracy as Dr. H. observes, for it is necessary to use a redundancy of oxygen gas to explode the whole of the hydrogen, but it is by no means certain that a small portion of the azote will not also undergo combustion

into nitric acid which will be absorbed by the water generated. On the whole, Dr. Henry estimates the entire mixed gasses produced by the electrization of the ammonia, to be composed of about 74 measures of hydrogen to 26 of azote.

The extreme labour of decomposing ammonia by mere electricity, led the author to attempt a shorter mode of analysis. Ammonia and atmospherical air will not explode by the electric spark in any proportions, but Dr. H. found that ammonia and oxygen gas when mingled in proper proportions, may be detonated over mercury by the electric spark with as much ease as a mixture of hydrogen and oxygen, and this experiment affords a very ready way of analyzing ammonia with infinitely less labour than by simple electrization, and with as much accuracy, provided proper precautions are observed.

With a greater proportion of pure oxygen gas to ammonia than that of three to one, or of ammonia to oxygen than that of three to 1.4 the mixture ceases to be combustible, but when the proportions best adapted to inflammation are used, the oxygen may be diluted with six times its bulk of common air, without losing its property of burning ammonia.

The products of the combustion of ammonia with oxygen vary essentially, according to the proportion of the gasses used. If the oxygen gas be as much as double the ammonia, the ammonia entirely disappears, as well as the hydrogen, and the only residue is azote with the excess of oxygen. The moment after the detonation, a white cloud settles on the inner surface of the tube, which is too small for analysis but is probably nitrat of ammonia, the nitric acid being formed by the oxygenation of a portion of the azote. Hence when the oxygen of the residue is removed by sulphuret of lime or any other eudiometrical process, the quantity of azote remaining is less than ought to be produced from the ammonia decomposed.

On the other hand when less oxygen is added at first to the ammonia than is sufficient to saturate all the hydrogen, that is to say, when the ammonia much exceeds the oxygen, no nitrat of ammonia appears, the mixture being free from cloudiness, and the mixed gas remaining after the first detonation will completely lose its hydrogen by a second admixture with oxygen and firing, and the azote will remain untouched.

Dr. Henry gives the results of comparative experiments in the two cases, that is, where an excess of oxygen was first employed; and where a deficiency was used. In the first case the oxy-

gen used was twice the measure of the ammonia: the whole was decomposed by a single explosion; and the hydrogen being estimated as equal to twice the bulk of the oxygen that disappeared, and the residuary azote being measured after the removal of the remaining oxygen by sulphuret of lime, the composition of 100 measures of ammonia was estimated to be 84.29 hydrogen, and 15.71 azote, numbers far remote from those given by all the other modes of analysis.

On the other hand, when the ammonia was fired with a deficiency of oxygen gas, 63 measures of the former were exploded with 33 of oxygen holding 1. of azotic impurity. These were diminished to 57 by the first explosion, and no part of the residue was absorbable either by water or by sulphuret of lime, shewing that the whole of the ammonia was decomposed, and that all the oxygen employed had been consumed. The remaining 57. measures (consisting of hydrogen and azote) were detonated with a further addition of 40. of oxygen, and the residue after this second detonation amounted to 60, which was further analyzed by sulphuret of lime. By calculating as above, reckoning 2 measures of hydrogen for every measure of oxygen actually consumed, it appears that the original 63 measures of ammonia furnished by decomposition 31.34 of azote and 88.66 of hydrogen, and hence 100. measures of ammonia would furnish 73.88 of hydrogen to 26.12 of azote.

Dr. Henry gives the results of six experiments on the decomposition of ammonia with a deficient proportion of oxygen, but we must confess that though they attest the care and fidelity of the experimenter, there is not quite sufficient agreement between them to lead us to place implicit confidence in this mode of operating, even in the most skilful and practised hands. The proportion of permanent gasses to the ammonia decomposed, (the azote being actually measured, and the hydrogen estimated by doubling the oxygen expended) varies not inconsiderably in the six experiments, the highest being 198½, the lowest 180.2 from 100 of ammonia. This shews a correspondent variation of from 66 to 72.2 of oxygen required to saturate all the hydrogen of 100. measures of ammonia, a variation which, however, is probably not more than may be expected in the best conducted experiments on such a complicated subject that requires such a variety of precautions to ensure a tolerable uniformity.

The author ascribes these variations chiefly to the great difficulty of expelling all adhering

moisture from every part of the materials and apparatus employed, and his general result is that the proportion of oxygen most precisely necessary to saturate 100. measures of ammonia is 67½, (or 100. of oxygen to 148 of ammonia) and the 100 measures of ammonia will afford about 136 measures of hydrogen and 47 of azote.

Dr. Henry also finds that ammonia will explode with nitrous oxyd and with nitrous gas.

A series of experiments on the decomposition of ammonia has also been published by Mr. A. B. Berthollet,^d the principal object of them was to examine a position laid down by Davy, (which we shall presently notice) that ammonia contains about $\frac{1}{11}$ of its weight of oxygen. M. A. B. Berthollet relates several experiments relative to the de-oxydation of iron in ammoniacal gas, and the decomposition of ammonia by its passage through an incandescent tube; and by electricity. In the latter method he gives as the mean of six experiments, that 1. measure of ammoniacal gas dilates by electrization into 2.04643 measures of hydrogen and azote.

His general results are that 1 *litre* of ammoniacal gas is decomposed into 2.046 *litres* of mixed gas, of which 1.545 is hydrogen, and 0.146 is azote. The weight of this quantity of hydrogen is 0.146 *grammes*, and that of the azote is 0.630 *grammes*, amounting in the whole to 0.776; and the weight of a litre of ammonia is 0.775 *grammes*, which agrees so nearly with the former as to demonstrate (if the data be correct) that ammonia contains no oxygen, nor other constituent part besides hydrogen and azote. It must be observed, however, that the experiments of this ingenious chemist (now no more) do not appear to have been conducted with the same scrupulous attention as those of Dr. Henry. In particular, the means used for depriving the gas of moisture were not so carefully attended to; and in the analysis by combustion with oxygen, an excess of this latter gas was used, which produced so much nitric acid as sensibly to redden litmus, and thus to embarrass the results. The presence of moisture will account for the greater expansion by electrization which this chemist gives; for Dr. Henry uniformly found, when the ammonia was at the driest, that the expansion never quite doubled the original volume of the ammonia.

Mr. Dalton agrees with Sir H. Davy and Dr. Henry, that the volume of ammonia is not doubled by decomposition, but that 100. measures of ammonia give from 185 to 190 of the mixed gasses, the respective proportions of

^d Mem. d'Arcueil, tom. 2.

which are about 28 measures of azote gas to 72 measures of hydrogen in the hundred.

100 measures of ammonia at .6 sp. gr. weigh 60 grains.

These become by decomposition 185. measures of mixed gas,

Namely 51.8 of azote which at .967 sp. gr. weigh 50.09

133.2 of hydrogen .08 10.65

60.74

Here the united weights of the hydrogen and azote equal and a little exceed the weight of the ammonia, and hence this alkali cannot contain any other constituent part than azote and hydrogen.

Mr. Dalton remarks on the analysis of ammonia by mixture with oxygen and detonation, that notwithstanding the elegance and expedition of Dr. Henry's method, it appears probable that a compound combustible such as ammonia is, can never be totally decomposed and one of its elements burnt, to the entire exclusion of the other. Thus in a mixture of carbonic oxyd and hydrogen, phosphorus, &c. where one of the elements seizes oxygen with more rapidity than the other, it is impracticable totally to oxygenate one of them, and leave the other untouched. With ammonia it is confessedly so where an excess of oxygen is used, (nitric acid appearing along with the water produced) and Mr. Dalton conceives that this is in some degree the case in whatever proportions they are fired. On the whole he prefers employing nitrous oxyd. When 100. measures of ammonia are exploded with 120. of nitrous oxyd, the gasses resulting are azote with only a very small portion of hydrogen. If to this a little hydrogen be added, and then an excess of oxygen, another explosion will determine the residuary hydrogen before explosion, which being deducted, there remain about 172 measures of azote, 120 of which come from the nitrous oxyd, and 52 from the ammonia, which gives after the rate of 28 per cent. of azote in volume on the evolved gasses.

We now proceed to the very interesting researches of Sir H. Davy on the nature of ammonia.

This eminent philosopher, after his most important discovery of the metallic bases of the fixed alkalies, was led from analogy to entertain the opinion that ammonia was probably, like the other alkalies, a compound of some peculiar metallic base and oxygen, and some experiments on the decomposition of ammonia, gave him reason to suppose that the hydrogen and azote evolved, were less than the entire weight of the

Mr. Dalton adds the following estimation.

alkali by about $\frac{1}{11}$, which eleventh part he concluded was the oxygen of the ammonia. This opinion, however, has been satisfactorily refuted by the laborious researches of Henry and Berthollet, just described; so that when ammonia is decomposed simply into hydrogen and azote, it appears that the united weights of these two elements equal the weight of the ammonia decomposed with as much accuracy as can be ever expected from such delicate experiments. This part of the controversy therefore seems to be put at rest, but another and highly curious set of phenomena happened to be discovered at the same time, which deserves particular notice.

Dr. Seebeck, of Jena, discovered in 1808, that when solid carbonat of ammonia is slightly moistened and placed in contact with mercury, and the whole connected with the Voltaic battery so that the mercury communicates with the negative pole and the salt with the positive pole, the mercury speedily becomes as soft as butter, expands in bulk, and has all the appearance of an *amalgam*. This when thrown into water effervesces strongly, the water becomes ammoniacal and the mercury returns to its original state. This experiment was repeated by Dr. Pontin and Professor Berzelius with some variation, and by them communicated to Sir H. Davy,* who immediately pursued the subject with his accustomed skill and ingenuity. His principal experiments are the following: a cavity was made in a piece of muriat of ammonia, and into this a large globule of mercury was introduced. The muriat was slightly moistened and placed on a plate of platina, which was made positive in the circuit of the large battery. The quicksilver was made negative by means of a platina wire. A strong effervescence immediately took place, the globule in a few minutes enlarged to five times its former dimensions, and metallic crystallizations shot from it as a centre round the body of the salt, which, when accidentally broken off from the mass, rapidly disappeared, emitting ammoniacal fumes and reproducing mercury.

When a piece of moistened carbonat of am-

* Phil. Trans. for 1808 and 1809.

monia was used, the appearances were the same, but a black matter formed in the cavity, apparently carbon.

It then occurred to Sir H. Davy that the strong deoxydating power of potassium or of sodium, might be made to produce the same effect on the ammoniacal salt without the intervention of any galvanic apparatus. Accordingly a small portion of potassium was dropped into the globule of mercury contained in the moistened cavity of the lump of muriat of ammonia, and immediately without any further apparatus, the mercury enlarged as before to six or seven times its bulk, and the same amalgam was formed, with this slight difference however, that it appeared to be more permanent, and to retain a portion of the potassium used.

This ammoniacal amalgam at the temperature of 70° or 80° is of the consistence of butter, at the freezing point it crystallizes into small undefined brilliant facets. When exposed to the air it soon becomes covered with a white crust of carbonat of ammonia. When thrown into water it produces about half its bulk of hydrogen, and returns to the state of running mercury, the water becoming ammoniacal. When thrown into muriatic acid gas, it instantly becomes coated with muriat of ammonia, and some hydrogen is disengaged. In sulphuric acid it becomes coated with sulphat of ammonia and sulphur.

The physical properties of this amalgam are very curious. The mercury appears to gain no more than about $\frac{1}{12000}$ th of its weight of new matter, but is thereby rendered solid, has its specific gravity diminished from 13.5 to less than 3. and retains its metallic colour, lustre, opacity, and conducting power.

Sir H. Davy made many attempts to obtain a peculiar metallic substance from this amalgam, by distillation, out of the contact of air, and thus to exhibit the supposed basis of ammonia (or *Ammonium*), in a separate state. But all these attempts failed, for under every circumstance the amalgam, when heated, gave out hydrogen and ammonia, and the mercury returned to its former state. In the most accurate experiments the proportions of these two gasses evolved were two of ammonia and one of hydrogen.

The nature of this amalgam is still very obscure, and much difference of opinion prevails on this subject among chemists. As it seems well ascertained that ammonia is resolvable solely into azote and hydrogen, it fol-

lows, that if ammonia is really an oxyd of some metallic base, azote and hydrogen, or one of them, must also be oxyds of some hitherto unknown substance, and this idea has been adopted by M. Berzelius, in his elaborate analytical researches, who supposes both hydrogen and azote to be oxyds of ammonium in different proportions. But when the ammoniacal amalgam is distilled, hydrogen and ammonia both appear, and the source of the hydrogen remains to be accounted for. This Sir H. Davy does, by supposing that as the amalgam is formed from moist substances, sufficient water adheres to it to afford oxygen by its decomposition, whilst its hydrogen unites with the amalgam. Nevertheless an excess of hydrogen is always produced in the distillation of the amalgam, even where the most scrupulous care is taken to exclude moisture.

Before we proceed with the other decompositions of ammonia, we shall relate the experiments of Messrs. Gay Lussac and Thenard,^f on the ammoniacal amalgam, in which they have repeated the experiments of Seebeck and Davy, and have added other interesting facts. They observe that when the amalgam is formed by the agency of galvanic electricity upon mercury in contact with moistened muriated ammonia, the acid of the salt and the oxygen of the water are carried to the positive pole, round which a dense and suffocating vapour of oxymuriatic acid collects. On the other hand, little or no gas of any kind escapes at the negative pole; but if the mercury is removed, then the effervescence is equally great at this pole also; from which they infer that the mercury simply absorbs the gas that would otherwise have escaped, and forms the amalgam.

When this amalgam is well dried and inclosed in a dry bottle of common air, and simply shaken for a few minutes, it is entirely decomposed, running mercury is produced, and hydrogen and ammoniacal gas are found mixed with the air of the bottle, which is no way altered when examined by Volta's eudiometer. Hence it appears that this amalgam can only exist under the electric influence, and as soon as this is destroyed by agitation, it returns to its elementary state. The amalgam made in Davy's method by mercury, potassium, and muriat of ammonia, without the agency of electricity, is more permanent, and remains in this state as long as it contains any potassium, but as soon as this is destroyed the amalgam is suddenly broken up. A quantity of this amalgam

^f Recherches Physico-Chimiques faites par M. M. Gay Lussac and Thenard.

was made, and the outer crust being removed by a knife, some of the inner part was taken up by a dry iron spoon, and put into a very dry glass tube inverted over mercury that had just been boiled. The tube being closed with a dry stopper was gently shaken, the amalgam was speedily decomposed, and a considerable quantity of gas was generated, consisting of ammonia and hydrogen in the proportion of about $2\frac{1}{2}$ to 1. The authors say that it is impossible that any moisture should here be present, since this is incompatible with potassium, and hence it appears that the amalgam cannot contain any basis of ammonia (supposing the alkali itself to be an oxyd of some unknown basis) since there is no obvious source from which this basis could abstract oxygen when the ammonia is regenerated. The authors endeavoured to ascertain the respective quantities of ammonia and of hydrogen given out during the decomposition of the amalgam, and they found that the mercury of the amalgam gave about 3.47 times its volume of hydrogen, and 4.22 of ammonia, which together made $\frac{10,000}{10,000}$ of the weight of the mercury.

On the action of Potassium on Ammonia.

When potassium is fused in ammoniacal gas,^s it is gradually changed into a very fusible olive-green substance, the ammonia disappears entirely, and part of the space which it occupied is filled with a quantity of hydrogen exactly equal to that which the potassium employed would have given, if thrown into water. This experiment may be performed in a bent tube over mercury, but care must be taken to shake off every particle of mercury from the potassium before it is deposited in the bend of the tube. Heat is then applied by a spirit lamp, and soon the potassium melts and becomes covered with a thin crust which directly after disappears, leaving the surface very brilliant, in a few seconds much ammonia is absorbed, and the olive-green substance is produced. By using sufficient ammonia all the potassium is changed to this olive-green matter. The quantity of ammonia absorbed varies from less than 100 to 136 times the bulk of the potassium, according to the heat employed. This olive-green substance is opaque, and heavier than water, when heated it melts and disengages ammonia, hydrogen, and azote, and then solidifies, still retaining its green colour. When exposed to the air at a common temperature, it gradually changes to ammonia and potash. When thrown into a heated crucible it suddenly

inflames. It burns rapidly when heated in oxygen gas. In water it heats and is immediately decomposed into potash and ammonia. The same effect takes place with acids. When heated with most of the metals, particularly the easily fusible ones, azote, ammonia, and sometimes hydrogen are disengaged, and an alloy of potassium with the metal used is obtained. M. M. Gay Lussac and Thenard examined with much care the effects produced by the application of different degrees of heat to this olive-green matter. The potassium was first put into a glass vessel with a certain quantity of pure hydrogen, to preserve the potassium from the contact of the mercury by which it was confined. Some pure ammoniacal gas was then added, and the whole was heated till the olive-green matter was produced, and when cold the absorption of ammonia was ascertained. The olive-green matter was then heated gradually to redness in the same vessel, without being removed, when it melted, boiled, and finally became solid again, blackish, and was no longer fusible. The remaining ammonia was then absorbed by water, and the azote and hydrogen analyzed in Volta's eudiometer. The general results of several experiments at different degrees of heat was, that as soon as the heat is sufficient to melt the olive-green matter, it begins to give out gas; that as long as the heat does not quite reach a cherry red, the gas is only ammonia; but by raising the heat to low redness, much hydrogen and azote become mixed with the ammonia given out; and at a higher heat, the gas becomes entirely hydrogen and azote, in the proportions of three to one, that is, in which they constitute ammonia; but however long the heat is continued, no more than about three-fifths of the quantity of gas originally absorbed by the potassium is expelled, so that it does not return to the state of potassium, but to a blackish infusible compound.

When this olive-green matter is confined over mercury and a drop of water is let up to it, much heat is excited, and a good deal of gas generated. By carefully adding water as long as any gas is generated, and assis'ing the process by a gentle heat, the whole is converted into a lump of moist solid potash and pure ammoniacal gas; and it was found that the ammonia obtained was almost equal to that which had been originally absorbed by the potassium, during its conversion into the olive-green matter, the slight difference in quantity

^s Recherches Physico-Chimiques, faites par M. M. Gay Lussac and Thenard.

being attributed to the ammonia absorbed by the moistened potash.

Sir H. Davy has also made a number of experiments on this singular compound with results some of which agree with those of Messrs. Gay Lussac and Thenard, and others differ from them. Some of these we shall mention,^b particularly the properties of the residuum of the olive-green substance after it has been heated to redness.

Its colour is black and in lustre it resembles plumbago. It is opaque, and brittle. It is a conductor of electricity. It does not fuse at a low red heat, but gives out a dark coloured sublimate. When exposed to the air at a common temperature it usually takes fire immediately and burns with a deep red light. When it is acted upon by water it heats, effervesces violently, and is resolved into ammonia and potash, with a little inflammable gas. It has no action upon quicksilver. It combines with sulphur and phosphorus by heat, and these compounds when wetted inflame and give out, the one sulphuretted, and the other phosphuretted hydrogen gas.

On distilling this substance in a tube of wrought platina in a very intense heat, potash was found with a quantity of potassium in the tube, and the gas was hydrogen with only a small proportion of azote.

The remarkable circumstance of this experiment is the deficiency of azote, this substance being in much less proportion than is required to constitute ammonia if the analysis of this alkali by electricity be at all correct.

After all that has been done on the analysis of ammonia, no satisfactory proof has yet been given that it can be decomposed into any other elements than azote and hydrogen.

AMMONIAC. (GUM.)

This gum has been examined by M. Braconnot.^a Exposed to a very gentle heat it loses 6 per cent. of its weight of mere moisture. Distilled *per se*, it yields half its weight of a brown empyreumatic oil containing ammonia. The coal contains phosphat and carbonat of lime.

Twenty five grammes of gum ammoniac were boiled with alcohol. The whole was dissolved except 5.8 grammes, and the solution remained clear on cooling. The insoluble portion was heated with water and the greater part dissolved, leaving however a grey glutinous mass insoluble both in water and spirit of wine.

The watery solution left a gum on evaporation, which was transparent, reddish yellow,

slightly bitter, and brittle: water easily dissolves it. It is abundantly precipitated by Goulard's extract, (but *not* by the acetite of lead) and only very partially by the nitrats of mercury and of lead. Lime water does not alter the solution, but oxalat of ammonia separates some oxalat of lime.

The resin produced by the evaporation of the alcoholic solution of gum ammonia is reddish yellow, transparent, brittle, but easily softens between the fingers. It has no taste. It unites with the alkalies with ease, even without heating, and the result is a saponaceous bitter solution.

Sulphuric acid dissolves the resin quietly in the cold, and the solution is separated by water.

When nitric acid is heated on this resin, it is suddenly decomposed with much red vapour. On evaporating the liquor to dryness a bitter resin is obtained which melts at a low heat, unites to alkalies, dissolves in alcohol and in water, and precipitates in part from the latter if it has been used boiling. Cold water also dissolves much of this bitter resin, giving a very beautiful yellow colour that stains the fingers strongly, and fixes itself easily and most firmly to silk and wool, so as to become unalterable by oxymuriatic acid, and even by alkalies if weak.

Gum ammoniac contains 18.4 per cent. of gum; 70. of resin; 4.4 of matter resembling gluten; and 6 of moisture.

AMPHIBOLE.

At the end of the article of STRAHLSTEIN it is remarked that a strong analogy subsists between the several varieties of Hornblende, Actynolite, Tremolite, and Asbestus. M. Haüy has since, in his *Tableau comparatif*, entered into an interesting discussion of this question, and from crystallographical resemblances, aided by the results of recent chemical analysis, has arranged them in the following manner.

The Labrador Hornblende forms a species by itself, under the name HYPERSTENE. The resplendent Hornblende (Schillerspath or Bronzite) forms a variety of DIALLAGE, the *metalloide*. A few of the Strahlsteins constitute the species EPIDOTE, (Thallite of Karsten) the remainder of the Hornblendes and Strahlstein, and all the Tremolites are included under the species Amphibole. Asbestus for the present ranks as a distinct species, but M. Haüy cites with evident favour the opinion of Cordier, who is for including it under Amphibole.

The following are the essential crystallographical characters of amphibole. Its primitive crystalline form is an oblique rhomboidal prism,

^a Phil. Trans. for 1809.

^a An. Chem. tom. 68.

the lateral planes of which unite under angles alternately of $124^{\circ} 34'$ and $55^{\circ} 26'$; and the ratio between the height of the prism and the diagonal passing through the obtuse angles of the summit is nearly as one to four.

The following are some of the most recent analyses.

Basaltic Hornbl. by Klappr.	Crystall H. from Cape de Gate, by Laugier.	Lamellar Hornbl. Actynolite of Zillerthal, by Klappr. by Laugier.
47.	42.	42.
8.	9.8	11.
2.	10.9	0.
26.	7.69	12.
15.	22.69	32.
	1.15 Oxide of Manganese	
98.	94.23	97.
		95.75

Fibrans Tremolite, by Klappr.	Comm. Tr. by Lowitz.	Grey Tremolite, by Laugier.	Baikalite, by Lowitz.
65.	52.	50.	44.
18.	20.	18.	20.
10.33	12.	25.	30.
0.16	0.	0.	6.
6.5		5.	Water and Carbonic acid
	12.		Carbonate of Lime
99.99	96.	98.	100

ANALCIME. Cubic Zeolite J. Wurfel Zeolith W.

It occurs limpid, or greyish-white; is amorphous, mammillated, radiated, or crystallized. Its form is a cube either perfect or with similar modifications round all the solid angles, producing symmetrical varieties that distinguish it from other species with which it might be confounded. It has rarely any natural joints visible, hence its fracture is compact conchoidal. It varies from translucent to transparent; usually scratches glass. sp. gr. 2.0.

Before the blowpipe it intumesces like borax and melts into a glass, emitting at the same time a phosphoric light. It is composed according to Vauquelin, of

58.	Silex
18.	Alumime
2.	Lime
10.	Soda
8.5	Water
96.5	
3.5	Loss

Var. 1. Sarcolite

Colour flesh red, opaque, somewhat softer than the preceding: consists, according to Vauquelin, of

50.	Silex
20.	Alumime
4.25	Lime
4.25	Soda
20.	Water,
98.5	
1.5	Loss

Analcime occurs chiefly in the glands of amygdaloid, and other trap rocks.

ANALYSIS OF VEGETABLE AND ANIMAL MATTER.

In an interesting memoir on this subject by Messrs. Gay Lussac and Thenard,* these chemists shew the great difficulties and the many causes of inaccuracy that attend the usual modes of analyzing vegetable and animal matter, and describe a new method of proceeding, by which they consider that they have been able to combine the carbon and hydrogen with the ut-

* Recherches, &c. tom. 2.

most quantity of oxygen with which they can unite, and thus by proper data to estimate the proportion of these constituent parts, and of oxygen, existing in the substance analyzed. The substance selected to oxygenate these elements is the oxymuriat of potash, and the matter to be analyzed is mixed with this salt and deflagrated in an apparatus contrived for the purpose, consisting of a thick glass tube set vertically in a fire with a lateral tube to conduct the generated gasses to a mercurial trough, and a cock above, the stopper of which is not perforated, but contains a small depression, into which a portion of the material to be analyzed is put, and by turning the cock downwards, this portion falls into the heated tube, and there deflagrates. The proportion of the oxymuriat requisite to burn completely the substance analyzed is found by previous trials in an open crucible, so much of the salt being required, that the residue after deflagration shall be quite white, or at least not carbonaceous; and in the actual experiment a considerable excess of the oxymuriat is employed. The materials are then accurately weighed (after being long dried at a boiling-water heat) and mixed in a mortar with a little water to an adhesive mass, which is divided by being thrust into a brass mould, and the pieces are rolled up by the fingers into little balls that they may drop clean from the stopper of the cock down into the deflagrating tube. These balls are again dried at the same heat before using.

The oxymuriat of potash is previously analyzed by itself in a proper apparatus to ascertain the proportion of oxygen which it furnishes, and to ensure an uniformity in this agent a considerable quantity of the salt is fused and then rubbed to powder by itself and kept for use. If the substance to be analyzed is a vegetable acid, it is combined with lime or barytes before mixture with the oxymuriat; and this calcareous or barytic salt is separately analyzed, and the carbonic acid that remains united with the earth after deflagration is properly estimated.

The earthy or other incombustible matter belonging to the substance to be examined is also separately estimated by calcining this substance by itself in a platina vessel and lixiviating the residue. The author gives at length all the precautions required in the management of the apparatus, both in preparing for the deflagration and in the estimation of the gasses produced. These last are supposed to be only carbonic acid, azote, and oxygen, the quantity of the oxymuriat being more than sufficient to convert into water all the hydrogen of the substance

analyzed. The probability of a little carburated hydrogen that may have escaped combustion is also acknowledged, and some allowance is made for it though apparently not in a very accurate way. The examination of the gaseous products of the deflagration is therefore thus conducted: 200 measures of the gas (standing over mercury) are added to 40 measures of pure hydrogen, and detonated by the electric spark. By this means the excess of oxygen is separated in the form of water, and the quantity of this excess is, of course, one third of the volume of the entire absorption after the electrization. The carbonic acid is absorbed by potash, and the residue is further examined for oxygen by the same means, and the ultimate residue is considered as azote. The data therefore from which the results of the analysis are made out are these: the proportion of combustible matter in the substance examined is previously found by calcination of another portion of the same; the actual quantity of oxygen employed in the deflagration is known by that of the oxymuriat used; the carbonic acid is absorbed by potash and its carbon estimated; the excess of oxygen is found by subsequent detonation with hydrogen; the hydrogen of the substance is presumed to form water with all the oxygen unaccounted for; and the azote exists in the residual azotic gas.

Fifteen vegetable substances were analyzed in this way, the particulars of some of which we shall give, and the results of the whole at the end of this article.

Sugar. 1000 parts of white sugar candy, exposed for many hours to a boiling water heat, lost only 8 parts of moisture. Some of the same sugar when calcined left only $\frac{1}{11}$ of residue. The quantities used for the experiment were 300 parts of sugar (exclusive of the moisture and insoluble residue) and 7 times as much oxymuriat of potash, the oxygen of which was 627 parts (by weight). This oxygen was recovered, all but two parts, in 449.9 parts of carbonic acid containing 322 of oxygen, and in an excess of 303. of oxygen discovered by detonation with hydrogen. Therefore the 300 of sugar had in fact only consumed 322 of oxygen, all of which went to form carbonic acid, of which the carbon was 127.4; and as no other product from the sugar but carbonic acid and water appeared, it would follow that sugar is composed of 42.47 per cent. of carbon, and 57.53 of water, either as such, or of oxygen and hydrogen in the exact proportions required to form water.

Gum Arabic, Starch, Sugar of Milk, Oak and Beech Wood, all agree with sugar in being composed merely of carbon, and of oxygen and hydrogen in the proportions required to form water.

Mucous Acid. This acid was prepared by heating sugar of milk with nitric acid. The solution soon became turbid, and much mucous acid was deposited, which was well washed and dried in a boiling-water heat. This acid left no residue whatever after calcination. On deflagrating a given portion of it with four times its weight of oxygen in the above-mentioned apparatus, and estimating the oxygen and carbonic acid of the product, a considerable excess of oxygen above the quantity required to form water with the hydrogen of the mucous acid was found, and hence the acid is considered as composed of carbon, water, and oxygen in excess.

Oxalic Acid. This acid was not mixed immediately with the oxymuriat of potash, but was first combined with lime (by being saturated with ammonia and precipitated by muriat of lime) and the dried oxalat of lime was calcined by itself in a platina crucible, and thus found to consist of 61.345 of acid and 38.655 of lime.

A given portion of the oxalat of lime was then deflagrated in the usual way with $1\frac{1}{2}$ its weight of the oxymuriat, and the results analyzed as before, but as a portion of the carbonic acid was retained in the deflagrating tube united with the lime and muriat of potash, this was separately analyzed by muriatic acid and the carbonic acid expelled.

Tartareous Acid. This acid was extracted in the usual way from tartrate of lime by sulphuric acid, but as it still retained a little of this latter acid even after repeated crystallization, it was dissolved in water and boiled with powdered litharge added gradually till the liquor no longer precipitated nitrat of barytes, by which means all the sulphuric acid was got rid of. The lead in solution was then separated by a current of sulphuretted hydrogen gas, and the clear liquid when evaporated gave pure tartareous acid. It was found impracticable however to make it into balls with oxymuriat of potash and water, as it deliquesced instantly on exposure to air.

The acid was therefore combined with lime, the tartrate of lime, dried at 212° , was found by calcination to consist of 77.577 of acid and 22.423 of lime, and this was further analyzed in the same manner as the oxalic acid.

Citric Acid. This was analyzed exactly as

the preceding acid. The citrat of lime consisted of 68.83 of acid and 31.17 of lime.

Acetic Acid. The acid here employed was first expelled from acetite of potash by sulphuric acid, and then heated with an excess of carbonat of barytes and the acetite of barytes evaporated and dried. But as this acetite could not be analyzed by simple calcination, (no continuance of heat being able to expell from the barytes all the carbonic acid formed by the combustion of the acetous) 30 grammes of the acetite were decomposed by sulphat of ammonia, and the sulphat of barytes was transferred, while still wet, to a platina crucible, and gradually ignited, till all the sulphat and acetite of ammonia adhering to it were expelled, and the sulphat of barytes remained pure. It weighed 25.443 grammes and contained 67 per cent. of barytes; and from these data acetite of barytes dried at 212° consists of 43.17 acid and 56.83 barytes. This acetite was then deflagrated as the last, and the results examined.

All the acids here examined contained a notable excess of oxygen, as will be seen in the tabular statement at the end of this article.

Resin of Turpentine, or Common Rosin. This was simply mixed with 12 times its weight of the oxymuriat and deflagrated in the apparatus. Scarcely any carburetted hydrogen was produced by the combustion, but carbonic acid, and much water, which last when collected and examined was neither acid nor alkaline, and the residue in the tube was pure muriat of potash. The large quantity of water produced indicated a proportional excess of hydrogen in the resin, so that by the usual mode of estimation this resin contained carbon, oxygen and hydrogen in the proportions for constituting water, and an excess of hydrogen.

Copal, Wax, and Olive Oil, were analyzed in the same manner, some little difference being observed in the manipulation of mixing them with the oxymuriat.

From the analysis of the above fifteen vegetable substances the authors consider that the following important inferences may be deduced, namely:

That a vegetable substance is acid whenever the oxygen which it contains exists in a larger proportion than will constitute water with the hydrogen present.

That a vegetable substance is resinous, or oily, or alcoholic, &c. when the oxygen is in less proportion than is required to form water with the hydrogen.

That when the oxygen and hydrogen are in the exact proportions in which they constitute water, the vegetable substance is analogous to sugar, gum, fecula, ligneous fibre, &c.

The analysis of some of the primary *animal* substances was then undertaken. In this case there is another element, azote, which requires particular notice. Whenever any animal matter is deflagrated with an *excess* of oxymuriat of potash, a quantity of nitrous acid gas is formed, which is the greatest where the heat required for combustion is the lowest. This circumstance would render the analysis in the way above described much more complicated and uncertain, unless some method could be found of preventing the formation of nitric acid. This the authors assert is effectually done by lowering the dose of the oxymuriat, so that with this, neither ammonia, nor nitric acid is produced, but the whole products are azotic gas, water, carbonic acid, and oxycarburetted hydrogen, and with proper precautions even the latter compound may be almost entirely prevented, and nearly the whole of it changed to carbonic acid and water. The requisite proportions of oxymuriat of potash and the animal matter employed must be found by previous trials with successive quantities. The animal matter, long dried at 212° , must be mixed thoroughly, first with thrice its weight of the oxymuriat and thrown into a crucible barely red-hot. If the residue of the deflagration is black it will shew that there is too little oxymuriat, if it is white the quantity of this salt may be too much, if it is greyish the proportions are sufficiently correct; or at any rate neither nitric acid nor ammonia will be produced in the deflagration, though perhaps there will be some carburetted hydrogen. Whenever any gas contains along with this gas a certain proportion of azote and carbonic acid gas, the presence of these will prevent the entire combustion of the carburetted hydrogen with any oxygen that may be added. It will therefore be necessary to add a small quantity of pure hydrogen to produce the detonation of the carburetted hydrogen, and its total conversion into carbonic acid and water.

Fibrine. The fibrine collected from ox-blood by stirring it as soon as drawn, was dried by long exposure to boiling-water heat; and a portion of it calcined by itself left only $\frac{1}{80}$ of fixed matter. Another portion was then mixed by long trituration with moist oxymuriat of potash, then made into balls and deflagrated in the same manner as the vegetable substances. The flame was very intense, and much water

condensed in the cooler part of the apparatus. The residue in the red-hot tube was a white saline mass consisting only of muriat of potash with the incombustible part of the fibrine. The results after subsequent analysis gave for the constituents of fibrine, carbon, oxygen and hydrogen in the proportions of water, some excess of hydrogen, and azote. The exact quantities will be found in the table.

Albumen from white of egg, *Caseum* or the pure cheese of milk, and *Gelatine* were analyzed exactly in the same way, except that the oxymuriat was added to the gelatine in solution (its proportion of dry gelatine being known) and both were dried together by boiling-water heat, this being the only way in which the two could be intimately mixed.

The general result of the analysis of these four animal substances is; that they all contain even more carbon than sugar or gum does, that in all the hydrogen exceeds the proportion required to form water with the oxygen present, and that the azote also found is not far from the proportion required to form ammonia with the excess of hydrogen. Hence (supposing the small differences to arise from the unavoidable errors in the practical part of the experiments) it is not unlikely that these animal substances might be resolved into carbon, water and ammonia. In this point of view these animal matters will bear a strong analogy with sugar, mucilage, &c. inasmuch as each consists of carbon, and other constituent parts in the exact proportion in which they will unite into some definite compound, being carbon and water in the vegetable substances; and carbon, water, and ammonia in the animal.

The authors have not carried their experimental research further, but they suggest the probability of further analogies between the vegetable and animal principles in the animal acids and animal oils.

We shall not give the general observations which are suggested to the authors of these important experiments, but shall only add the tables of the actual results. It will be understood that the substances analyzed are taken, exclusive of their incombustible earthy metallic and saline contents, and that no azote is considered as entering into the vegetable principle. In the animal substances all the hydrogen and azote are estimated as constituting ammonia, allowing some excess or deficiency of this principle, to be attributable to accidental errors in the experiments.

Table of the constituent parts of the following Vegetable Substances.

Substance analyzed. 100 parts	Carbon.	Oxygen.	Hydrogen	Or supposing the Hydrogen and Oxygen to form water.		
				Carbon.	Water.	Oxygen in excess.
Sugar	42.47	50.63	6.90	42.47	57.53	0
Gum Arabic . .	42.23	50.84	6.93	42.23	57.77	0
Starch	43.55	49.68	6.77	43.55	56.45	0
Sugar of Milk . .	38.825	53.834	7.341	38.825	61.175	0
Oak wood . . .	52.53	41.78	5.69	52.53	47.47	0
Beech wood . .	51.45	42.73	5.82	51.45	48.55	0
Mucous Acid . .	33.69	62.67	3.62	33.69	30.16	36.15
Oxalic A. . . .	26.57	70.69	2.74	26.57	22.87	50.56
Tartareous A. . .	24.05	69.32	6.63	24.05	56.24	20.71
Citric A. . . .	33.81	59.86	6.33	33.81	52.75	13.44
Acetic A. . . .	50.22	44.15	5.63	50.22	46.91	2.87
						Hydrogen in excess,
Rosin	75.94	13.34	10.72	75.94	15.16	8.90
Copal	76.81	10.61	12.58	76.81	12.05	11.14
Wax	81.79	5.54	12.67	81.79	6.30	11.91
Olive Oil . . .	77.21	9.43	13.36	77.21	10.71	12.08

Table of the constituent parts of the following Animal Substances.

Substance analyzed. 100 parts	Carbon.	Oxygen.	Hydrogen	Azote.	Or, supposing the Oxygen to form Water with part of the Hydrogen, and the remain- der of the Hydrogen to form Ammonia with the Azote.			
					Carbon.	Water.	Ammonia	Azote, excess or deficiency.
Albumen	52.883	23.872	7.540	15.705	52.883	27.127	23.182	-3.191
Caseum	59.781	11.409	7.429	21.381	59.781	12.964	31.778	-4.623
Gelatine	47.881	27.207	7.914	16.998	47.881	30.917	22.743	-1.541
Fibrin	53.360	19.865	7.021	19.934	53.360	22.369	23.463	+0.808

ANDALUSITE. Feldspath Apyre H.

Its colour is flesh red verging on rose red. It occurs massive and crystallized in rectangular prisms. Its fracture is imperfectly foliated; the natural joints are parallel to the sides of a nearly rectangular prism, and to one of the diagonals of its transverse section. It is translucent; is harder than quartz, and sometimes even than spinelle. Sp. gr. 3.1.

It is infusible before the blow-pipe without addition. It is composed, according to Vauquelin, of

52. alumine
38. silix
8. potash
2. oxide of iron

100.

This mineral in its crystalline form approaches very near to felspar, and in its analysis differs only in containing an excess of alumine; to this excess its hardness and infusibility are no doubt to be attributed. It was the opinion of Count Bournon (and M. Haüy seems inclined to agree with him) that andalusite is felspar intimately mixed with corundum.

It occurs in granite in Spain, France, Saxony, Ireland, and Devonshire.

ANTHOPHYLLITE.

This mineral has a perfectly foliated structure, and though not crystallized, is divisible in the direction of its natural joints, parallel to the sides of a rectangular prism; two of these sections present brightly shining surfaces, and are much more easily obtained than the others. Besides these four joints two others may be perceived on close inspection with a bright light, dividing the prism diagonally. Its specific gravity is 3.2. Its hardness is about equal to that of glass. Its colour is brownish, with more or less of a pseudo-metallic lustre. It affords by analysis, according to M. John,

62.66	silica
13.33	alumina
4.0	magnesia
12.0	oxide of iron
3.25	oxide of manganese
1.43	water
96.67	

ANTIMONY.

§ 1. Ores of.

Red Antimony.

This substance was supposed to be a native kermes or hydrosulphuret of antimony, but, according to a recent analysis by Klaproth,* it affords

67.5	antimony
10.8	oxygen
19.7	sulphur
98.0	

Native Antimony.

A specimen of this substance from Andreasberg in the Hartz, has been analysed by Klaproth,* with the following result:

98.	antimony
1.	silver
0.25	iron
99.25	

White Antimony.

A specimen of this mineral in quadrilateral tabular crystals, from Przibram in Bohemia, was analysed by Klaproth,* with the especial object of ascertaining whether it contained any muriatic acid as had been suspected by Haquet. For this purpose 25 grs. of the mineral were fused with 200 grs. of carbonated potash: the mass was then digested in water and the alkali was supersaturated by nitric acid. On the addition of nitrate of silver no precipitation took place, hence the white antimony may be considered as a pure oxide of antimony.

Antimony with Nickel.

This ore has hitherto been found only in a mine at Treusberg in Nassau.^d It is composed in part of broad parallel plates of a shining white, resembling antimony, and in part of a compact leaden grey substance with a glimmering lustre. Its sp. gr. is 5.65. Its hardness is superior to that of grey antimony. When exposed on charcoal to the action of the blow-pipe it melts readily, and disengages white vapours of an arsenical odour, and which more or less adhere to the charcoal in form of a yellowish powder; by degrees the globule becomes less fusible, and there remains behind a white brittle refractory button.

By digestion in nitric acid a portion of the ore is converted into a yellowish white voluminous powder, and the remainder combines with the menstruum into a green liquor.

The powder, by digestion in muriatic acid slowly dissolves, with the exception of a small residue of a yellowish colour which consists of sulphur, of sand, and of a little arseniate of iron. This solution when diluted with water lets fall a white precipitate consisting of muriate of antimony and oxide of arsenic, inseparable from each other with perfect accuracy, according to Vauquelin, by any known chemical process, but in a considerable degree decomposable by distillation with sulphur which raises the principal part of the arsenic in the form of realgar. What remains in the retort is sulphuret of antimony with a little arsenic and lead.

The green nitric solution contains nickel, arsenic, and a little lead.

From the result of this examination, and from the different degree of fusibility exhibited by different portions of the ore, it is considered by Vauquelin as a mixture of sulphuret of antimony, of arsenical nickel, a little galena and iron pyrites.

* Klapr. Ess. ii. 147.

^b Ann. de Chim. lxxxiii. p. 229.

^c Haüy tab. comp. 299. Klap. Ess. ii. 142.

^d Ann. de Chim. lxxxv. p. 26.

The same ore has since been subjected to a careful analysis by Klaproth.*

1. 300 grs. separated as accurately as possible from the oxide of iron with which it is naturally mixed, were digested in cold aqua regia, composed of 5 parts muriatic acid and 1 part nitric. The undissolved residue was again subjected to the same process, after which what remained undissolved was well washed in alcohol and dried. Its weight was 51 grs. of which 41 grs. burnt off with all the appearances attending the combustion of sulphur, leaving behind 10 grs. which dissolved entirely in aqua regia.

2. The solutions were mixed together in a retort and much concentrated; water being then added a copious precipitate fell down. The supernatant liquor was again concentrated, and a second precipitate was obtained as before by the addition of water.

3. After separating the precipitate the fluid was again concentrated, and appeared of a grass-green colour; ammonia was then added in excess which threw down a brown oxide of iron weighing after calcination 13.5 grs.

4. The ammoniacal solution was evaporated to dryness, and the saline mass gently ignited; the residue which had the appearance of yellowish brown micaceous scales was digested in muriatic acid, in which it entirely dissolved. By means of caustic potash a precipitate of an apple-green colour was obtained, which by calcination left behind 93.25 grs. of pure oxide of nickel of a slate grey colour, indicating 70.75 grs. of metallic nickel.

5. The precipitate N° 2, proved on examination to be arseniate of antimony, but all attempts at an accurate decomposition of it were fruitless.

Thus foiled, M. Klaproth had recourse to the following method. 200 grs. of the levigated ore were ignited with 600 grs. of nitre; the mass was then lixiviated and well washed. The lixivium on being slightly acidulated with nitric acid gave no precipitate, a proof that no antimony had been taken up. Lime water was then added and a voluminous precipitate of arseniate of lime fell down. This latter after being washed and dried was mixed with one-third of its weight of charcoal and sublimed in a retort, and afforded 22 grs. of metallic arsenic.

The matter insoluble in the lixivium was digested in aqua regia in which it dissolved almost entirely, and from this solution water

threw down a precipitate weighing 116 grs. equivalent to 89 grs. of metallic antimony.

Hence the constituent parts of this mineral, omitting the oxide of iron which is considered by M. Klaproth as accidental, are

25.25	metallic nickel
47.75	antimony
11.75	arsenic
15.25	sulphur

100.

§ 2. Chemical Properties.

Much difference of opinion has arisen with regard to the number and composition of the oxyds of antimony. Thenard reckons as many as six, Proust only two. According to the latter chemist the lowest oxyd or *suboxyd* is composed of 81.5 metal to 18.5 oxygen or 22.7 oxygen upon 100 of metal; and the highest oxyd or *peroxyd* contains 77 metal to 23 oxygen; or 29.87 oxygen upon 100 of metal.

Pr. Berzelius reckons four oxyds of antimony, two of which have the characters of acids. We have not the particulars of the experiments, but the following are stated as the results:*

The first or lowest oxyd is obtained by exposing antimony to the action of the positive side of the voltaic pile. It is grey, and when in contact with acids that do not themselves impart oxygen, part of the oxyd returns to the metallic state, and the rest passes to the second oxyd and dissolves.

The second oxyd is the base of emetic tartar, and most of the other antimonial salts. This is white and fusible.

The third oxyd is also white but infusible at a white heat. It possesses all the characters of an acid, and is called by the author *Stibious Acid*. The white oxyd of antimony by nitre is in fact a salt composed of potash with an excess of this stibious acid, and is decomposed by boiling water into a neutral soluble stibiate of potash, and an insoluble portion with still greater excess of acid. From this soluble stibiate of potash professor Berzelius has formed many other neutral stibiates.

The fourth oxyd is straw coloured and is an acid with higher oxydation than the former, and therefore has the name of *Stibic Acid*. At a high temperature it gives out oxygen and passes to the state of *Stibious Acid*.

* Klapr. Ess. ii. 134.

* An. Chim. tom. 83, p. 169.

The respective proportions of metal and oxygen in these compounds are the following.

The second oxyd contains 100. antimony to 18.6 oxygen.

The third oxyd contains 100. antimony to 27.9 oxygen.

The fourth oxyd contains 100. antimony to 37.2 oxygen.

These three oxyds therefore have their oxygen in the proportions of 1, $1\frac{1}{2}$ and 2.

The elements of the first oxyd are not given. It may be presumed (according to the theory of definite proportions) to contain either 9.3 or $\frac{9.3}{2} = 4.65$ oxygen to 100. of metal.

The same author also gives for the elements of the sulphuret of antimony, 100. of antimony to 37.25 of sulphur.

Tartarized Antimony.—Tartar Emetic.

A very elaborate examination of this salt and of the various modes of preparing it, has been given by a practical chemist, Mr. R. Phillips,^b who has shewn the great uncertainty of success in following the mode laid down by the London College of Physicians in their last Pharmacopœia. This uncertainty arises from the strong tendency in this metal to pass from the state of suboxyd (in which alone it is soluble in tartar) to that of insoluble peroxyd. Mr. Phillips has given as an improvement in the process, the employment of the sub-sulphat of antimony as the base to be afterwards boiled with a solution of an equal weight of cream of tartar, which crystallizes with the tartar into the tartarized antimony, or triple tartrate of antimony and potash. The sub-sulphat is prepared by boiling and evaporating to dryness a mixture of sulphuric acid with about half its weight of metallic antimony, and afterwards washing out of the residue all the uncombined sulphuric acid, leaving a tasteless sub-sulphat, in which the oxyd must be at a low state of oxydation, since it dissolves copiously with tartar and forms with it the tartar emetic. As all tartar contains tartrate of lime, some sulphat of lime is also produced by the acid of the sub-sulphat, which partly crystallizes along with the emetic tartar, but is separated by a second solution.

APLOME.

This mineral occurs in rhomboidal dodecahedrons of a deep brown colour inclining more or less to orange, striated externally parallel to the short diagonals of the rhombs. On ex-

posing fragments of this substance to a bright light, indications of laminæ may be perceived, the direction of which, combined with that of the striæ, affords reason for supposing that its primitive form is a cube. Its specific gravity is 3.44. It scratches quartz though slightly. Its fracture is uneven, passing into small conchoidal with a moderate lustre. It is opaque and in very minute crystals translucent. Before the blow-pipe it is fusible into a blackish glass. It affords by analysis, according to Laugier,

40.	silex
20.	alumine
14.5	oxyd of iron
14.5	lime
2.	oxyd of manganese
2.	ferruginous silex
2.	volatile matter

95.0

It occurs in Siberia on the banks of the river Lena.

APOPHYLLITE. See ICHTHYOPHTHALMITE.

ARCTIZITE. See WERNERITE.

ARENDALITE. See STRAHLSTEIN, glassy.

ARGIL, native.

A small portion of this mineral, not sufficient for a regular analysis, was examined by Fourcroy, who states it to contain about 24 per cent. of sulphate of lime (Ann. de Mus. I. 45); since which it has been formally analyzed by M. Simon of Berlin, and by Bucholz, with the following results.^a

Simon.		Bucholz.
32.5	—	31.0 alumine
19.25	—	21.5 sulphuric acid
0.45	—	2.0 oxyd of iron
0.35	—	lime
0.45	—	silex
47.	—	45. water
100.00	—	99.5

ARSENIC.—ARSENICATED HYDROGEN. ARSENIATS.

§ 1. Ores of Arsenic.

Mispickel.

Some recent experiments on this ore have been made by M. Chevreul.^b When mispickel is heated in a glass retort, there rises a sublimate consisting of metallic arsenic with a very small portion of orpiment, and the residue

^a Experimental Examination of the Pharmacopœia. ^a Klapp. Dict. Chim. art. *Alumine native.*

^b Journ. des Mines, xxix. p. 459.

consists of sulphuret of iron, retaining some traces of arsenic. The component parts of this ore, as deduced from a separate analysis of the sublimate and of the residue, are

43.418 arsenic
34.938 iron
20.134 sulphur
98.490

Iron is well known to have a stronger affinity for sulphur than arsenic has, and as in the present instance the proportion of iron and sulphur is just sufficient to form the sub-sulphuret, it appears probable that mispickel is a combination of iron pyrites and of metallic arsenic.

Arsenical Pyrites.^c

The primitive form of this substance is a strait rhomboidal prism, the angles of which are alternately $111^{\circ}18'$ and $68^{\circ}42'$.

It is composed, according to Lampadius, of

58.9 iron
42.1 arsenic
101.0

§ 2. *Chemical Properties.*

It is often desirable to detect minute quantities of arsenic mixed with other substances. Some of these means have been already mentioned under this article, (*Ch. Dict. I. p. 105,*) but another should be noticed on account of the great extent of its operation. It consists in first dissolving the arsenic in water, adding a small quantity of sub-carbonat of potash, and then applying nitrat of silver. The process is thus described by Mr. Hume who first suggested it.^d Put in a glass flask two or three grains of the powder suspected to be arsenic, add eight ounces of distilled water and gradually bring it to boil over a lamp or clear fire. Then add a grain or two of sub-carbonat of potash or soda, and shake the mixture. When clear, pour some of the solution into a glass, and dip just under the surface of the liquid a stick of lunar caustic, and a beautiful yellow precipitate will appear, which can hardly be confounded with any other substance.

Dr. Marcet^e has given a variation of this process which has the advantage of being performed in a few seconds. Pour some of the

clear fluid suspected to contain arsenic into any glass vessel, stir into it a glass rod dipped in pure ammonia, and immediately after another glass rod wetted with nitrat of silver. The same orange yellow precipitate will immediately appear. Care should be taken to add only a very small quantity of each of the reagents, particularly of the ammonia. In either mode it is obvious that any muriatic acid present will give a precipitate with nitrat of silver, and this metallic salt will also be decomposed by the carbonated potash or soda where this method is used, so that it is not the mere appearance of any precipitate, but of an *orange-yellow* precipitate that will determine the presence of arsenic. Where the arsenic is in the state of arsenic acid the colour of the precipitate will be brick-red.

This precipitate is a compound of oxyd of silver and arsenic, either partially or entirely oxydated, and when heated *per se*, especially on charcoal, the arsenic sublimes and leaves a globule of pure silver.

Orpiment and Realgar. The following distinctive characters of these substances are given by M. Thenard.^f

Both of them melt and sublime unaltered in close vessels and without giving out any sulphureous acid. Both are acted on by the sulphuric nitric and oxymuriatic acids. Sulphuric acid acts much more easily on orpiment than on realgar. In both cases sulphureous acid and arsenious acid are formed, but more of the former acid and less of the latter are produced with orpiment than with realgar. Nitric acid is easily decomposed even without heat on both these substances, and sulphur and arsenious acid are formed. The fixed alkalies dissolve both without heat; when potash is used, hydro-sulphuret of potash and arsenite of potash are formed, for on adding lime-water to the solution a copious white precipitate appears, which, when treated with carbonat of potash, gives a liquid that yields abundance of arsenious acid on saturation with muriatic acid and evaporation.

Sulphur fused with realgar converts it into orpiment, and arsenic added to orpiment changes it to realgar. Three parts of sulphur and four of arsenic form orpiment: and one part of sulphur with three of arsenic form realgar. The latter is the most fusible of the two. Orpiment made artificially by sublimation is

^c Haüy. Table Comp. 95, 272.

^d Phil. Mag. vol. 33.

^e Medico-Chirurgical Transact. vol. 2, p. 15, and vol. 3. 343.

^f An. Chim. No. 177, p. 284.

yellow and transparent as is native orpiment after being melted; but both assume a very bright clear yellow when reduced to powder. The orpiment produced in the moist way by a soluble arsenite, a hydro-sulphuret, and an acid, is always of the same opake bright yellow as the other orpiment when pulverized.

Arsenic Acid. Arsenious Acid. Arsenite, and Arseniate of Lead.

According to the experiments of Proust, 100 parts of arsenic combine with 33 of oxygen to form the white oxyd, or the *Arsenious Acid*, and with 53 of oxygen to form the *Arsenic acid*. This subject has been examined by professor Berzelius with the view of accommodating these numbers to the system of definite proportions explained under the article AFFINITY in this appendix. It is there assumed that when any base is capable of more than one degree of oxygenation, the lowest number multiplied by 2, 3, &c. or by the intermediate halves $1\frac{1}{2}$, $2\frac{1}{2}$, &c. will give all the other degrees. Hence the oxygen of arsenious acid must bear one or other of these proportions to that of arsenic acid. Another rule is, that when a compound consists of two oxydated substances the oxygen of the base must bear an equally definite proportion with that of the acid; hence in any of the metallic arseniates (arseniat of lead for example) the oxygen of the arsenic acid must bear a definite and simple proportion to that of the oxyd of lead. Both these questions are here examined.*

Arsenious acid contains, according to Proust, 33.33 of oxygen to 100. metal, and arsenic acid contains 53 oxygen to 100. metal, and other chemists give rather less. The nearest definite proportion between these is $1\frac{1}{2}$ times 33, which gives 50. The following are professor Berzelius's experiments.

200 parts of sub-oxyd of lead dissolved in nitric acid, evaporated to expell the excess of acid and again dissolved in water, were precipitated by *arsenite* of potash. The precipitate of arsenite of lead, which was at first light and flocculent, easily separated by boiling, and when dried weighed 391.26, but on being ignited gave out 6.65 of water and 16.51 of uncombined arsenious acid. The neutral salt remaining weighed 368.1.

A similar experiment gave arsenite of lead in the proportion of 368.8. Hence the composition of arsenite of lead, taking the former estimate, is

Arsenious acid . 45.667 — 100.000
Sub-oxyd of lead . 54.333 — 118.977

100.000 — 218.977

Sub-oxyd of lead was found from very careful experiments to contain 7.15 per cent. of oxygen, and therefore the 118.977 contain 8.5068 oxygen. Hence the 100. of arsenious acid must contain some proportion of oxygen, which is a simple multiple of 8.5068, and as three times this quantity very nearly agrees with the experiments of Proust, arsenious acid is assumed to be composed of,

Arsenic . . 74.48 — 100.000
Oxygen . . 25.52 — 34.263

100.00 — 134.263

The composition of the arsenic acid is also deduced from its combination with lead.

100. parts of arseniat of lead were dissolved in nitric acid, and precipitated by sulphat of ammonia. The supernatant liquor was evaporated to dryness to expell the excess of nitric acid, and the soluble portion was again dissolved in water and compleatly neutralized by ammonia. This separated a little sulphat of lead which was added to the other portion that remained insoluble in water. The whole sulphat of lead thus obtained was 95.59. A second experiment gave nearly similar results. This quantity of sulphat of lead much exceeded that obtained by Klaproth and Rose, by the simple addition of sulphat of ammonia to arseniat of lead in nitric acid, but professor Berzelius shews that these eminent chemists were not aware of the solubility of a portion of the sulphat of lead in the excess of acid.

Hence arseniate of lead consists of,

Arsenic acid . 29.6317 — 100.0
Sub-oxyd of lead 70.3683 — 237.5

100.0000 — 337.5

The 237.5 of sub-oxyd of lead contain 16.981 of oxygen. Hence the composition of 100. parts of arsenic acid (according to the rules before laid down) must contain such a portion of oxygen as is produced by a simple multiplication of 16.981, and at the same time will afford such a proportion between the metal and the oxygen as will give an increase of oxygen upon 100. parts of the metal, in a simple (or nearly simple) ratio to the oxygen

* An. Chim. tom. 80. p. 9.

of the arsenious acid which is 34.263. These conditions will be fulfilled (making a reasonable allowance for errors) by taking the oxygen in 100. parts of arsenic acid as double that of the sub-oxyl of lead with which it is saturated, that is, $16.981 \times 2 = 33.962$.

Arsenic acid will therefore contain,

Arsenic . .	66.038 — 100
Oxygen . .	33.962 — 51.428
	100.000 — 151.428

And as the arsenious acid contains 34.263 oxygen to 100. of metal, the arsenic acid will contain to the same quantity of metal $1\frac{1}{2}$ times $34.263 = 51.3945$, within a very small difference.

It has been already mentioned, under the article *affinity*, that wherever the ratio between two portions of the same substance that unite to another substance is expressed by a fraction (as $1\frac{1}{2}$) there is reason to suppose some *minimum* of combination which will convert these fractional numbers to integers. This in the present instance will be produced by assuming the *minimum* of oxydation of arsenic, as either half or a quarter of that of the arsenious acid. It is well known that when metallic arsenic is exposed to the air it loses its lustre and becomes covered with a blackish brown powder. The author exposed 200. parts of metallic arsenic for two months to the air, at the end of which time it entirely fell into a bulky black powder. The increase of weight in that time was 16.2, and in another month the further increase was only 0.75, being in all 16.95, or in the proportion of 8.475 oxygen to 100. of metal, and $8.475 \times 6 = 50.85$, which does not much differ from 51.428, the highest term of oxygenation. Hence it is probable that the arsenious acid is 4 times the *minimum* of oxygenation, and the arsenic acid 6 times.

The *Arsenite of Lead* mentioned above has the following properties: when dry it is white, and by friction it becomes apparently even more electric than sulphur. When melted it is transparent, and remains so after cooling and then becomes yellowish, but of a dark green if any copper is present. Arsenite of lead kept at a red heat gives out arsenious acid, and is gradually changed to arseniate of lead.

Arsenicated Hydrogen.

Under the article *Alkaline Basis* in this appendix we have mentioned the alloy of potassium and arsenic, and the production of

arsenicated hydrogen by adding water to this alloy. It was there found that when 100 parts of arsenicated hydrogen are kept in contact with melted tin, the latter extracts all the arsenic and then the hydrogen expands to 140 parts. (See the above article.)

ASPARAGUS.

The juice of this plant has been examined with much care and skill by M. Robriquet.* A quantity of asparagus was first bruised and the juice extracted by pressure, and passed through a coarse cloth, leaving a fecula behind. The juice in this state had a strong unpleasant smell, and was a dirty yellow colour inclining to green. The fecula, treated by boiling alcohol, only partially dissolved, and the insoluble portion examined in various ways strongly resembled animal gluten, in drying to a horny mass which by combustion gave much ammonia. The part soluble in hot alcohol deposited on cooling a substance a good deal like wax; whilst the supernatant solution contained a species of resin.

The filtered recent asparagus juice was sensibly acid and reddened litmus. After boiling, to separate some remaining flocculi of albumen, it was evaporated nearly to dryness, and then digested with alcohol, and the part untouched by this agent was dissolved in water. The alcoholic solution gave a very slight precipitate with acetite of lead, and this metallic precipitate was not again soluble in distilled vinegar, thus shewing that the acid of the asparagus-juice was not the malic. Another portion of the juice was assayed by distillation with sulphuric acid, and a quantity of acetic acid united with potash was obtained. Still the acid of the juice was not clearly made out, and it was afterwards analyzed with great attention. To obtain it pure the expressed juice of the plant was first coagulated by heat, and the clear liquor filtered. Into this liquor was poured acetite of lead as long as any precipitate formed, and this last when well washed was digested with a third of its weight of sulphuric acid diluted with three parts of water, and moderately heated. The sulphat of lead thus formed remained at the bottom, and the clear supernatant liquor was evaporated to an extractive consistence, and treated with alcohol twice successively (excluding a little insoluble matter each time) till a clear solution in the spirit was obtained. This acid was brownish, had a very sour taste mixed with some unpleasant flavour particularly when heated, and gave soluble salts with the alkalies and insoluble

* An. Chim. tom. 55.

ones with the earths. It decomposed the earthy acetites by simple affinity, and also many metallic salts, particularly those of iron, copper and lead, and the salt produced by its mixture with acetite of lead was in the form of white flocculi *insoluble* in distilled vinegar. In this last property it differed decisively from the malic acid, and also in decomposing the sulphats and acetites of iron and copper. To ascertain the nature of this acid of asparagus-juice it was precipitated by lime-water, and the washed precipitate calcined in a silver crucible till all the carbonaceous matter had disappeared, and a grey calcareous salt remained insoluble in water. This was boiled and dissolved in distilled vinegar and precipitated unaltered by ammonia, and then was found to be *phosphat of lime*.

To prove still further that this supposed peculiar acid is the phosphoric, its combination with lead (made by precipitating acetite of lead) was fused with the blow-pipe, and the button assumed on cooling that polyhedral form which is so characteristic of *phosphat of lead*.

Asparagus-juice does however contain some peculiar substances. A quantity of the juice was concentrated and left for a considerable time to itself in M. Vauquelin's laboratory. After a while a good many crystals formed in the liquor, obviously of two distinct kinds, which were examined by Messrs. Vauquelin and Robriquet.^b

One of these (which indeed had before been noticed by M. Robriquet) had the following properties:

When obtained pure by repeated crystallization it assumes the form of rhomboidal prisms. It is quite white, moderately soluble in water, and neither acid nor alkaline; infusion of galls, acetite of lead, oxalat of ammonia, muriat of barytes, and hydro-sulphuret of barytes, produce no change in it: it is insoluble in alcohol. It contains neither ammonia nor earth: when ignited *per se* in a platina crucible, it swells up and exhales pungent vapours, and leaves a bulky coal but absolutely insipid, and the ash is not in the least degree alkaline. Nitric acid decomposes this salt and produces a yellow bitter liquor containing much ammonia formed in the process.

This salt therefore seems at present to be a peculiar crystallizable substance containing none of the known acids, alkalies, earths, or other salifiable bases.

The other crystals formed in the asparagus liquor were equally white, but soft and imperfectly crystallized in fine needles having a sensibly saccharine taste, like that of manna. It has not been further examined.

AUGITE.

In addition to the analysis of the Volcanic Augite from Etna by Vauquelin, already cited, we now have analyses of the Augite of Frascati,^c and of Giuliana^d in Sicily by Klaproth.

Fras.		Giul.	
48.	—	55.	silice
24.	—	10.	lime
8.75	—	1.75	magnesia
5.	—	16.5	alumine
12.	—	13.75	oxyd of iron
1.	—	—	oxyd of manganese
a trace	—	—	potash
—	—	1.5	water
98.75		98.5	

The Norwegian Augite has also been analyzed by Simon and Roux^e with the following results.

Simon		Roux	
50.25	—	45.	silice
25.5	—	30.5	lime
3.5	—	3.	alumine
7.	—	—	magnesia
10.5	—	16.	oxyd of iron
2.25	—	5.	oxyd of manganese
0.5	—	—	water
a trace	—	—	chrome
99.5		99.5	

On examining however the details of the analysis by M. Roux, it is manifest that he failed to precipitate the whole of the alumine, and that the whole of the magnesia was left in the lime.

Var. I. Coccolite, *Korniger Augit*, *Kars-ten*.

Its colour is a deep green; it presents an assemblage of slightly coherent granular concretions of various sizes up to that of a small pea, several of which resemble crystals with their solid angles worn off, and M. Haüy, by mechanical division, has actually reduced them to tetrahedral prisms. Internally this mineral is shining with a vitreous lustre; its fracture is foliated; it is translucent, scratches glass, and gives a few sparks with steel. Sp. gr. 3.3.

It is infusible by the blowpipe without ad-

^b An. Chim. tom. 55.

^c An. Chim. lxxvii. 225.

^d Klapr. Diet. de Chim.

^e Journ. de Mines.

dition; with soda it forms an olive green slaggy glass, and with borax a pale yellow semitransparent glass. It has been analyzed by Vauquelin, and appears to consist of

50.	sillex
24.	lime
10.	magnesia
1.5	alumine
7.	oxyd of iron
3.	oxyd of manganese

95.5
4.5 loss

It occurs in the iron mines of Sudermania; and of Arendahl in Norway.

Var. 2. *Sahlite*. Malacolite, *D'Andrada*.

Its colour is pale greyish green; its external lustre is vitreous approaching to waxy; it is translucent; it scratches glass slightly, but gives no sparks with steel, and is easily frangible. Fracture shining and strait lamellar with a triple cleavage. It is generally in the form of coarsely granular distinct concretions, but also occurs massive with a broad lamellar fracture, or crystallized in rectangular parallelepipeds slightly bevelled on their lateral edges, or in prisms terminated by convex planes. Sp. gr. 3.23.

It is infusible before the blowpipe without addition.

It occurs in Sweden at the silver mines of Sahla; and at Buoen in Norway.

Its component parts, according to an analysis by Vauquelin, are

53.	sillex
20.	lime
19.	magnesia
3.	alumine
4.	oxyds of iron and of manganese

99.
1. loss.

To this variety, on the authority of M. Haüy, are also to be referred the Mussite and Alalite of M. Bonvoisin, of which M. Haüy had once formed a new species under the name Diopside.^a

Its colour is greenish or yellowish white: it occurs crystallized in tetrahedral and dodecahedral prisms, or in deeply striated sub-cylindrical grains, or massive with a lamellar fracture. It scarcely scratches glass, and is fusible before the blowpipe into a greyish mass. It is composed, according to Laugier, of

57.	sillex
16.5	lime
18.25	magnesia
6.	oxyds of iron and of manganese
97.75	
2.25	loss.

The Mussite occurs in the Commune of Balme-de-Mussa, Department of the Po, in a vein accompanied by granular carbonate of lime.

The Alalite occurs near the village of Ala, in the mountain of Ciarmetta, in a vein accompanied by garnets.

AUTOMOLITE. *Spinelle zincifère, H.*

This substance occurs only crystallized. Its primitive form is the regular octohedron, besides which it presents the transposed octohedron. The crystals are for the most part very small, rarely equalling in size a small nut. Its specific gravity is 4.69 (4.26 Ekeberg). It scratches quartz. Its colour is a deep bluish-green: the entire crystals are opaque, but in thin fragments it is more or less semi-transparent. Its fracture is lamellar, parallel to the faces of the crystal, but in other directions is uneven and scaly with a vitreous lustre.

Before the blowpipe it neither melts nor undergoes any change of colour. With phosphate of soda it runs into a clear colourless bead.

It was first analyzed by Ekeberg, and afterwards by Vauquelin, with the following results.

Ekeb.	Vauq.
60.	— 42. alumine
4.	— 4. sillex
24.	— 28. oxyd of zinc
9.	— 5. oxyd of iron
0.	— 17. sulphur
0.	— 4. portion of the mineral
97.	100. remaining unaltered

It occurs at Fahlun in Sweden.

It was at first supposed to be corundum mixed with zinc, but the prevailing opinion at present is that it is spinelle pleonaste loaded with blende.

AZOTE WITH OXYGEN, Compounds of. The specific gravity of azotic gas is to that of hydrogen, as 13 to 1.^b 100 cubical inches of it at a mean temperature and pressure, weigh between 29. and 30. grains.

There are at least three specific compounds of azote and oxygen; viz. Nitrous Oxyd, Nitrous Gas, and Nitrous Acid Gas.

^a Journ. des Mines, No. 115.

^b Davy's Elements.

Nitrous Oxyd. The specific gravity of this gas is to that of hydrogen as 21. to 1; and 100. cubic inches weigh between 48 and 49 grains. When one cubic inch of nitrous oxyd is mixed with the same quantity of hydrogen and exploded by the electric spark, water is formed, and the only residue is one cubic inch of azote. Now as one cubic inch of hydrogen requires half a cubic inch of oxygen to become water, it follows that one cubic inch of nitrous oxyd contains one cubic inch of azote and half a cubic inch of oxygen, condensed into the space of a single cubic inch.

In like manner, if dry charcoal be ignited in one cubic inch of nitrous oxyd, the products are half a cubic inch of carbonic acid and one cubic inch of azote. Hence, as oxygen neither gains nor loses in bulk by its conversion into carbonic acid, the composition of nitrous oxyd is found, as before, to be two volumes of azote and one of oxygen, condensed into the space of two volumes. Hence too it consists, by weight, of 26 of azote and 15 of oxygen.

Nitrous Gas. Its specific gravity is to that of hydrogen as 14 to 1; and 100 cubic inches weigh about 32 grains. When several metals, such as arsenic, zinc, or potassium, are heated in nitrous gas, it oxydates them and affords half its volume of azote. If charcoal is ignited in two cubic inches of nitrous gas, the products are one cubic inch of carbonic acid and one of azote. Hence as oxygen gas neither expands nor contracts by conversion into carbonic acid gas, nitrous gas consists of equal volumes of azote and oxygen not condensed by their chemical union; or it contains (by weight) 13 parts of azote to 15 of oxygen. When two cubic inches of nitrous gas are exposed to the action of muriat of tin, or sulphuretted alkali, part of the oxygen of the gas is absorbed, and one cubic inch of nitrous oxyd is left, which exactly harmonizes with their relative proportions of oxygen and azote; for one cubic inch of nitrous oxyd contains, as already mentioned, one cubic inch of azote and half a cubic inch of oxygen; and therefore the portion of oxygen extracted by the sulphuret is exactly half a cubic inch of oxygen.

Nitrous Acid Gas. When oxygen and nitrous gas are mixed together, red fumes of *nitrous acid gas* are produced, and a condensation of the bulk of the gasses takes place. If the experiment be made over water, a rapid and total absorption takes place, and the water becomes acidulous. Much difference of opinion

still exists as to the respective proportions in which nitrous gas and oxygen unite, nor is it very easy to make accurate experiments, since the acid gas is absorbed both by water and mercury.

According to Sir H. Davy, when two volumes of nitrous gas and one volume of oxygen, both previously dried, are mixed together in a vessel exhausted of air, they become condensed to half their volume, and form a deep orange-coloured gas, which is nitrous acid gas. Calculating from the condensation, the specific gravity of this gas must be to that of hydrogen as about 28. to 1; and 100 grains of it must weigh 65.3 grains. When water is admitted to this gas there is a rapid absorption, and the water gains a tint of green. This proportion of two volumes of nitrous gas to one volume of oxygen is the highest in oxygenation that can be produced as a pure and distinct gaseous body; for when the oxygen is actually mixed in greater proportion, the condensation is such as only to indicate the formation of the above nitrous acid gas, with an excess of uncombined oxygen. The same happens when water is admitted, the acid gas absorbed retaining no greater a proportion of oxygen than when in a gaseous state. But on the other hand, when this nitrous acid gas is absorbed by an alkaline base, a portion of nitrous gas is always evolved, leaving the remainder in a state of a higher relative oxygenation than gaseous nitric acid. This the author concludes from many experiments to be in the proportion of 2 volumes of nitrous gas and $1\frac{1}{2}$ of oxygen, and this forms the *pale nitric acid* as it exists in solution in water, or as the acid part of the alkaline, earthy, and metallic nitrats. Nitric acid therefore, according to this opinion, when once obtained from the decomposition of the nitrats can exist unchanged in solution in water; though water alone cannot condense from its gaseous state a mixture of two volumes of nitrous gas and $1\frac{1}{2}$ of oxygen, which is here given as the composition of nitric acid. This liquid acid again may be made to absorb different quantities of nitrous gas, when it becomes yellow, orange, blue, and finally blueish-green, when saturated with nitrous gas.

It has been mentioned that oxygen and nitrous gas unite in different proportions, and these are in a good measure regulated by the quantities of each gas employed, and the diameter of the vessel in which they are mixed. Mr. Dalton gives the following interesting re-

sults of his own experience on this subject.* When two measures of nitrous gas are put to one measure of oxygen gas in a tube one-third of an inch in diameter and five inches in length, standing over water, as soon as the diminution has apparently ceased, which will be in half a minute, if the residuary gas is transferred into another tube, it will be found that one measure of oxygen and 1.8 of nitrous gas have disappeared.

When 4 measures of oxygen are put to 1.3 of nitrous gas in a tube two-tenths of an inch in diameter and ten inches long so as to fill it, it will be found that 1 measure of oxygen will combine with 1.3 of nitrous gas in four or five minutes.

When 1 measure of oxygen and 5 of nitrous gas are mixed together so as to form a thin stratum of air not more than $\frac{1}{8}$ th of an inch in depth (as under a common tumbler) the oxygen will take up from 3 to $3\frac{1}{2}$ measures of nitrous gas in a moment, without any agitation. If

equal measures are mixed, then 1 oxygen takes about 2.2 nitrous gas.

Thus it appears that these two gasses will unite in a great variety of proportions, according to the relative quantity of either gas employed, and the suddenness of their union. But according to Mr. Dalton, there is however a definite *maximum* and *minimum* of saturation, which includes all the other proportions. The *maximum* of oxygenation actually observed is that in which 1 measure of oxygen combines with 1.3 of nitrous gas; and the *minimum* is that of 1 measure of oxygen to 3.6 of nitrous gas; but as the actual maximum does not harmonize with any definite proportion, Mr. D. assumes hypothetically the real *maximum* to be 1 of oxygen with .9 of nitrous gas, to which he gives the term *oxynitric acid*. The constitution of nitric acid he infers from other observations to be 1 measure of oxygen to 1.8 of nitrous gas. Hence all the compounds of nitrous gas and oxygen will be thus expressed:

measure	measures	
1 oxygen	with .9 nitrous gas	form oxynitric acid
1 —————	1.8 —————	nitric acid
1 —————	3.6 —————	nitrous acid

And all the intermediate degrees of saturation are considered as mixtures of two or more of the above compounds.

One of the most important considerations relative to nitric acid is the determination of the quantity of real acid in a watery solution of a given specific gravity. The temperature of ebullition of nitric acid of different densities varies in a very singular manner. When weak nitric acid is boiled or distilled, the weakest portion comes over first; but when the acid is concentrated, the strongest portion comes over first, as observed by Dr. R. Perceval (*see Chim. Dict. art. Nitric acid*). From these facts, Mr. Dalton inferred that an acid of some one strength, and only one, was incapable of any change of strength by distillation, so that when a portion of this was distilled, the distilled part and the residue would have the same specific gravity. It was desirable to find the actual strength of this acid, as these circumstances shew a nice adjustment of affinities between the acid and the water; and this acid Mr. Dalton has found by many experiments to be of the specific gravity of 1.42. The boiling temperature of this acid is higher than that of any other nitric acid, stronger or weaker, being 248° , which indeed is the immediate reason of the

reduction of strength of all the other nitric acids to that of 1.42 when submitted to gradual distillation; and of the stronger acids parting with the portion above 1.42 and the weaker acids with that below this standard. Hence the continued boiling of any nitric acid tends to bring the portion in the retort to the specific gravity of 1.42, and to raise the temperature to 248° . Mr. Dalton calculates this acid of 1.42 to be composed of 2 atoms of water to 1 atom of real acid. The acid of 1 of real acid to 4 of water has the specific gravity of 1.30, and is remarkable for freezing the most easily of all, namely at -2° . according to Mr. Cavendish.

With respect to the quantity of real acid in a solution of given specific gravity, Mr. Dalton follows the method employed by Kirwan, assuming that fused nitre consists of 47.5 per cent. by weight of real acid and 52.5 of potash. Mr. Dalton's estimate of the real acid of different mixtures of nitric acid and water, agrees very nearly with those of Mr. Kirwan, but Mr. D. has given the important addition of the boiling temperature of each. The following is his table of the quantity of real acid in 100 parts of liquid nitric acid at the temperature of 60° .

* New System, part ii. p. 327.

Acid per cent. by weight.	Acid per cent. by measure.	Specific gravity.	Boiling point.
100	175?	1.75?	30°?
82.7	134	1.62	100°
72.5	112	1.54	175°
68	102	1.50	210°
58.4	84.7	1.45	240°
54.4	77.2	1.42	248°
51.2	71.7	1.40	247°
44.3	59.8	1.35	242°
37.4	48.6	1.30	236°
32.3	40.7	1.26	232°
28.5	34.8	1.22	229°
25.4	30.5	1.20	226°
23	27.1	1.18	223°
21	24.6	1.17	221°
19.3	22.4	1.16	220°
17.8	20.5	1.15	219°
16.6	18.9	1.14	219°

M. Gay Lussac,^d in repeating Mr. Dalton's experiments on the different proportions of oxygen absorbed by nitrous gas according to the circumstances of the experiment, has endeavoured to reduce all the definite combinations of azote and oxygen to very simple numbers, estimating the gasses by measure.

Nitrous gas is composed of equal volumes of azote and oxygen, which unite without condensation; and the author considers nitric acid as composed of 200 measures of nitrous gas and 100 measures of oxygen, or (what amounts to the same) it consists of 100 measures of azote to 200 of oxygen. The intermediate term of saturation is that which constitutes *nitrous acid gas*, and which when absorbed by water gives the *liquid nitrous acid*, the acid part of the *nitrites*. The author finds, agreeably to Mr. Dalton's experiments, that the production of this intermediate acid depends on the circumstances of the experiment and the proportions of each gas employed. If 200 measures of nitrous gas are put into a narrow tube over water, and 200 measures of oxygen are added, or if this order is reversed, and the oxygen added first, 300 measures will disappear and 100 measures of oxygen will remain unaltered. The water that has absorbed these 300 measures will be a solution of *nitric acid*, and with potash will form common nitre. Therefore nitric acid contains 2 parts by measure of nitrous gas to one of oxygen. But if the oxygen be not in excess, if for example 100 measures of oxygen be added to 400 measures of nitrous

gas, the entire absorption will be 400 measures, and 100 measures of nitrous gas will remain. The water that has absorbed these 400 measures will now be *nitrous acid*, and with potash will form small needled crystals of *nitrite of potash*, which give out copious red fumes on the addition of any strong acid. To make this experiment correctly it should be in a wide vessel and without agitation, so that the water in absorbing the nitrous acid gas may not also absorb a portion of the residuary nitrous gas. *Nitrous acid* therefore is produced by the union of 300 measures of nitrous gas with 100 of oxygen; or (what amounts to the same) it consists of 150 measures of azote to 250 of oxygen. It is best made by dissolving nitrous acid gas in water, which becomes blue, green, and finally orange yellow, according to the strength of the acid and the quantity of gas absorbed. Hence it is that the orange yellow acid may be changed to the green, and the green to the blue, merely by proper dilution with water, which diminishes the relative strength of the acid in a given quantity.

The liquid nitrous acid is also made by passing nitrous acid gas into liquid *nitric acid*, which then becomes blue, green, or yellow orange, according to the concentration of the nitric acid.

M. Gay Lussac gives the following estimate of the composition of the oxyds of azote, viz.

Nitrous oxyd consists of 100 measures of azote with 50 measures of oxygen; or, by weight, of 63.72 of azote and 36.28 oxygen.

Nitrous gas consists of equal measures of azote and oxygen; or, by weight, of 46.757 of azote and 53.243 of oxygen.

Nitrous acid gas consists of 300 measures of nitrous gas to 100 measures of oxygen; or, by weight, of 34.507 of azote and 65.493 of oxygen.

Nitric acid consists of 100 measures of azote to 200 measures of oxygen, or of 200 measures of nitrous gas to 100 measures of oxygen; or, by weight, of 30.512 of azote to 69.488 of oxygen.

AZOTIZED OXYMURIATIC ACID, or AZOTIZED CHLORINE. (*Acide Muriatique oxiazoté.*)

Under this term we shall describe a new and most remarkable compound of azote and oxy-muriatic acid, which appears to be the most violently detonating substance hitherto known. The first notice of the fact of this discovery published in this country is (we believe) con-

^d Mem. d'Arcueil, tom. 2.

tained in the extract of a letter published by Sir H. Davy,^a which announces the discovery of a compound of azote and chlorine appearing as an oil heavier than water, that detonates with all the violence of the fulminating metals by the mere heat of the hand, separating thereby in the gaseous form the two elements of which it is composed, evolving much heat and light. The writer also adds that this dangerous property had cost to the discoverer both an eye and a finger.

With this obscure hint of the nature of this substance, added to the recollection of the accidental formation of an oil by passing chlorine gas through nitrat of ammonia suggested by Mr. Children, Sir H. Davy has been enabled to produce this oily detonating compound, which indeed is a very simple process, and, as we are informed in the memoir on the subject, had nearly cost him the same unfortunate sacrifice of an eye as to the first discoverer (M. Dulong) in the attempt to become more familiar with the properties of this formidable compound.

M. Dulong has since made known all the particulars of this discovery in a paper lately read to the French Institute, of which a general abstract is given by Messrs. Thenard and Berthollet.^b

From this and Sir H. Davy's memoir we learn the following particulars. Azote and oxymuriatic gas have no known action on each other when in the gaseous form, but when oxymuriatic gas is passed through a solution of the nitrat of ammonia, the oxalat, or many other ammoniacal salts, it is rapidly absorbed and a film collects on the surface, which is soon resolved into distinct drops of a yellowish oil that sinks to the bottom of the liquid, and is the detonating compound in question. A weak solution of pure ammonia will answer as well as the neu-

tral ammoniacal salt. A temperature of about 40° or 50° answers the best for its production. Sir H. Davy obtained it immediately by *shaking* in a phial a saturated solution of nitrated ammonia with about six cubic inches of chlorine, a mode of operating which appears attended with extreme hazard, for even when a large quantity of the gas was merely passed through a Woulfe's apparatus charged with the different ammoniacal solutions, the whole exploded violently and shattered the apparatus to pieces.

This detonating oil is yellowish, but quite transparent and highly liquid. Its smell is very nauseous, resembling that of the compound of carbonic oxyd and chlorine. It evaporates rapidly but silently when exposed to the air at a common temperature, but when slightly warmed it explodes vehemently, insomuch that it is dangerous to warm in any glass vessel a globule of the oil no bigger than a grain of mustard seed. When this oil merely touches many combustible matters, even without increasing the temperature, it explodes very violently, so as generally to shatter any glass vessel. This is the case when a globule of it is thrown into olive oil, turpentine, or naphtha. But with alcohol it only loses gradually its explosive property and becomes a white oily matter. When a particle of this oil touches phosphorus, or phosphorized alcohol and ether, it explodes with equal violence. It has no effect on muriatic or sulphuric acid, zinc, tinfoil or sulphur. M. Dulong attempted to analyze it by adding it, and the liquor in which it was formed, to a vessel containing copper filings. Muriated oxyd of copper was produced and azotic gas given out. It seems therefore to be without doubt a compound of chlorine and azote, but its unmanageable properties make its analysis an affair of difficulty and some danger.

B

BARIUM. BARYTES.

The basis of the earth barytes was first obtained by the eminent discoverer of the alkaline bases in the following way:^c pure barytes was made into a paste with water, and a small cavity made in it to receive a globule of mercury, the barytes was laid on a slip of platina which was made positive in a voltaic battery, and the globule of mercury was rendered negative. In this state the barytes was deprived of oxygen, and its base, *Barium*, was obtained amalgamated with the mercury, from which it was separated

by evaporating the mercury. Barium thus procured is of a dark grey colour, with a low metallic lustre, and heavier than sulphuric acid. When thrown into water it effervesces, hydrogen is given off from one portion of the decomposed water whilst its oxygen unites with the barium, and barytes is reproduced and dissolves in the water.

Sir H. Davy estimates the elements of barytes to be about 89.7 per cent. of barium, and 10.3 of oxygen.

Barytes is the first oxyd of barium. Its

^a Phil. Trans. for 1813.

^b Ann. de Chim. tom. lxxxvi. p. 37.

^c Davy's Elements.

properties have been fully described in our original article, and the difference between the pure barytes obtained from the nitrat and that procured from the crystals of barytes formed by solution in water, has been mentioned in the article *Alkali* in this appendix.

Peroxyd of Barium. According to the experiments of Messrs. Gay Lussac and Thenard, barytes can absorb oxygen, and thus produce an oxyd of barium of a higher state of oxydation than barytes.^b For this purpose some dry oxygen gas was passed into a glass tube over mercury, and along with it some fragments of pure barytes arising from the calcined nitrat. On applying the heat of a lamp, the oxygen was very rapidly absorbed, and the barytes appeared as if glazed on its surface, and became greyer.

The glass was then filled with hydrogen and heated as before. The hydrogen was absorbed in large quantity, and sparks were seen to proceed from the barytes. No water was vaporized, so that all of this fluid, which must have been produced by this absorption of hydrogen, was absorbed by the barytes, which then became very fusible.

The experiment was repeated with similar success with barytes prepared by calcining the carbonat of barytes with lamp-black in an intense heat; so that the effect could not have been produced in the first instance by any undecomposed nitric acid.

BENZON. BENZOIC ACID. BENZOATS.

We have to mention some additional facts relative to this resin and its products, which are among the most interesting of this class of vegetable substances.^a

When benzoin is gradually heated in moderately dilute nitric acid, it is dissolved into a light yellow liquid, which on cooling gradually deposits nearly the whole of the benzoic acid, whilst the resin appears to remain dissolved. This solution is totally decomposed by water.

Sulphuric acid dissolves benzoin into a deep red liquid, but carbonizes a portion of it. The solution gives a lilac precipitate with water. Acetic acid dissolves this resin even in the cold. When saturated by boiling, much benzoic acid separates on cooling.

When these acids are added to the solution of benzoin in alcohol, a precipitate is formed (with all but the nitric) which is probably a compound of the resin and acid, and an excess of the same acid generally redissolves a part of this precipitate. Nitric acid on the other hand does

not render the alcoholic solution turbid, but gives it a dark red colour, so that this acid seems to have a greater solvent power over the resin of benzoin.

Benzoic Acid. Scarcely two thirds of the whole acid contained in benzoin is procured by mere sublimation. Scheele's process (mentioned in our original article) gives the purest acid.

Some German chemists have also employed carbonat of potash or soda, as an intermede for obtaining this acid. Benzoin, boiled repeatedly with about a tenth of its weight of carbonat of soda and sufficient water, the resin being taken out two or three times and triturated, and again boiled with the same liquor, yields at last nearly the whole of its acid to the soda, and the solution of benzoat of soda deposits its acid on adding the sulphuric acid.

Benzoic acid is soluble in most of the acids, but separable from them by dilution with water.

A singular fluid compound of benzoic acid and camphor is mentioned by Mr. Gowa,^c to be produced by adding a definite quantity of water to a solution of both these substances in alcohol.

Twenty grains of benzoic acid and as much camphor dissolved in half an ounce of common alcohol, and then diluted with as much water, gradually separates into two liquids, both of which are quite transparent if the acid is free from resin, but yellowish if otherwise.

Both the upper and lower liquids appear to be compounds of alcohol, water, benzoic acid and camphor. The lower, which has an oily appearance, is strongly acid and aromatic, and by evaporation forms crystals apparently composed of benzoic acid and camphor. Cold water added to this liquid immediately decomposes it, the benzoic acid being precipitated in the form of shining crystals, and the camphor floating on the top. The upper fluid on standing for a time, sometimes deposits large crystals floating upon the lower stratum, which are chiefly benzoic acid, but altered from its usual crystallized form, probably by the presence of some camphor.

It requires pretty exactly the above mentioned proportion of benzoic acid, camphor, alcohol and water, to produce this singular separation into two distinct solutions, for when more of the spirituous menstruum is used, the whole remains as one uniform solution, and when a greater proportion of water is employed, much of the camphor and part of the acid separate.

Mr. Bucholz has examined some of the leading properties of the benzoic acid, with a view

^b Recherches, tom. I. p. 169.

^a Brande in Phil. Journ. vol. x.

^c Phil. Journ. vol. xxviii. p. 28.

of comparing them with the camphoric acid, some chemists having considered these two acids as nearly identical. The properties of the *Camphoric Acid* will be given under that article; those of the benzoic are the following:

Ten grains of benzoic acid were mixed with 500 grains of distilled water, and shaken in a phial for half an hour. The whole liquid was passed through a filter, the weight of which when dry was previously known, and after again drying there was found an addition of $7\frac{1}{2}$ grains of weight produced by the undissolved acid. Hence Benzoic acid requires 200 times its weight of cold water for perfect solution. On the other hand it requires only 24 parts of boiling water, so that by far the greater part of the acid must again separate on cooling.

An hundred grains of cold alcohol dissolve by agitation about 56 grains of benzoic acid; and boiling alcohol dissolves nearly its own weight of the acid.

Benzoat of Lime. Benzoic acid boiled with carbonat of lime and water is gradually neutralized; and 50 grains of the acid require in this way about 20 grains of the calcareous earth, the pure lime of which is about 13 grains. The solution when much reduced by evaporation gives on cooling a number of shining silky needled crystals, often radiating from a common center; their taste is sweetish and somewhat earthy.

Though this benzoat of lime is prepared with the purest acid, and is perfectly white, when heated by itself in a close vessel it gives a liquid empyreumatic oil, smelling of the resin of benzoin. Benzoat of lime requires 20 times its weight of cold water for perfect solution.

Benzoat of Potash. This salt crystallizes when the acid is slightly in excess, forming small needles which require ten parts of cold water for solution. The neutralized salt is much more soluble and deliquescent.

It is to be observed that when most of the neutral benzoats are evaporated, part of the acid flies off, leaving the salt with a slight excess of base. This however is not the case with the benzoat of ammonia, the alkali being full as volatile as the acid. This property is of some importance as it gives a reason for a preference of the benzoat of ammonia in a very important use in analytical chemistry, to which it has lately been applied by Professor Berzelius.

This eminent chemist has found that the benzoic acid may be applied to the separation of iron from manganese, with equal success with the *Succinic*, and it has the advantage of being

much cheaper and more easily obtained. It is necessary for this purpose that the solution containing the mixed oxyds should be previously neutralized with accuracy, and then the benzoat of ammonia may be added as long as any precipitate falls down. This precipitate is merely benzoat of iron, and all the manganese remains in solution.

Not only will this salt separate iron from manganese, but as M. Hisinger has observed, it will equally separate it from all earthy salts, and from nickel, cobalt and many other metals, none of which are precipitated by the benzoat when properly applied.

(This will be further described in this appendix under the article IRON.)

BILDSTEIN.

From a recent analysis of this substance by Vauquelin,* it appears to be composed of

- 56. Silex
- 29. Alumine
- 2. Lime
- 7. Potash
- 1. Oxide of Iron
- 5. Water

100

It is interesting to observe, that in this mineral the character of unctuousity is by no means indicative of the presence of magnesia. The analogy also, as to chemical composition, between bildstein, mica, and felspar, is deserving of notice.

BILE.

This important fluid has been analyzed by Thenard,^a a very skilful chemist, who has discovered in the bile of some animals what he considers as a new animal principle, to which he gives the name of *Picromel*, on account of its sweet and pungent taste.

The experiments on ox-gall are the following. A quantity of it was distilled to dryness in a retort, by which it lost from $\frac{7}{8}$ to $\frac{8}{9}$ of its weight of mere water a little flavoured. The dry yellow residue was calcined carefully in a platina or silver crucible kept scarcely at a cherry-red, by which it gave 22 per cent. of carbonaceous residue containing soda, common salt, phosphat and sulphat of soda, and phosphat of lime.

The uncombined soda amounted to no more than $\frac{1}{200}$ of the original gall, which appeared much too small a quantity to be the intermede whereby the resin of this bile might be held in solution. Neither is the precipitate formed by acids at all equal to the whole of the solid

* Journ. des Mines. No. lxxxviii. p. 247.

^a Mem. d'Arcueil, tom. i.

matter which may be extracted from the bile, which is another reason for supposing some other substance besides soda which holds the resinous matter of bile in perfect solution. The analysis of ox-gall was thus conducted: A little nitric acid was first added, which precipitated a peculiar yellow matter along with a very little resin, which last was afterwards obtained pure by alcohol. The gall was filtered, and into it was poured a solution of sub-acetite of lead (made with 8 parts of common acetite and one of litharge) by which an insoluble compound of oxyd of lead and the resin of the gall fell down, (separable from each other by weak nitric acid) and the supernatant liquor was freed from the excess of the salt of lead by a current of sulphuretted hydrogen. The clear filtered liquor was evaporated to dryness, and gave the *Picromel* mixed with acetite of soda. The distinguishing properties of picromel, according to M. Thenard, are its pungent sweetish taste, and the great solvent power which it exercises over the resin of the bile; so that by adding again the due proportions of this resin, of picromel, of the yellow matter separable by nitric acid, and of soda, the author obtained an uniform liquid exactly resembling the original bile from which these substances had been extracted. Of 800 parts of ox-gall the author finds 700 of water, 24 of resin, $60\frac{1}{2}$ of picromel, about 4 of yellow matter, and 4 of soda, and the rest salts of soda and lime.

Picromel dissolves both in water and in alcohol, does not crystallize, and forms a triple compound with resin and soda, highly soluble in water, and not decomposable by acids, alkalies, and earthy salts; but it is separated by some metallic salts.

The resin of bile is green, bitter, soluble in alcohol, and separable thence by water, and soluble in alkalies, and in some acids, but not in all.

It appears however in the author's second memoir on this subject, that the picromel is not so certainly obtained in the above method; for he says that if too much of the acetite of lead is added, the picromel itself is separated, so that it is necessary to assay the precipitate from time to time, and as soon as it becomes totally soluble in weak nitric acid, it will shew that all the resin has been separated, and that the picromel itself begins to precipitate.

M. Thenard gives the result of the analysis of the bile of different animals, and finds no picromel in human bile, this secretion containing chiefly water, albumen, a peculiar resin, soda, and some salts.

Professor Berzelius in his analysis of bile,^b entirely denies the existence of this peculiar substance, *picromel*, as a distinct animal principle, and seems to consider nearly the whole of the solid contents of the bile (the saline part excepted) as one peculiar albuminous substance, which partly precipitates in the form of a resin when some mineral acid is added; and therefore this supposed resin is a compound of the peculiar bitter albumen of bile with a small portion of the acid employed. This biliary matter is soluble in water, even without the assistance of alkali or of any other intermede; and it forms two compounds with some acids, one soluble, the other not so, and therefore precipitated, and in the form of a resin. But the acetous acid which gives soluble compounds with the albumen of blood does the same with biliary albumen, and hence no precipitate follows the addition of this acid to bile.

The biliary matter may be obtained pure in the following way: mix fresh bile with sulphuric acid diluted with 3 or 4 parts of water, a yellow precipitate whose nature is hardly known first appears and must be separated; then continue adding more of the acid as long as any thing falls down, decant the fluid part and edulcorate the remaining green resiniform substance. This, which is in fact a compound of biliary albumen and sulphuric acid, may be deprived of its acid either by digestion with carbonat of barytes and water, or by solution in alcohol, and digesting the liquid with carbonat of lime as long as it reddens litmus. The clear liquor then contains the pure biliary albumen, which is to be evaporated to dryness. This gives a green solution in water closely resembling the natural bile. The quantity of this biliary matter he estimates at $\frac{8}{100}$ of the whole bile.

BIRDLIME.

This substance has been commonly supposed to be analogous to vegetable gluten, like that of wheat, but it does not appear to have been analyzed with any care till Bouillon la Grange examined it, and he has found the following properties.^a

The birdlime here employed was that of the inner bark of the holly, prepared by bruising the bark in a mortar, boiling it with water for four or five hours, throwing away the liquor, and putting the residue in earthen pots, and keeping it in a damp cellar till it was mouldy and viscous, moistening it now and then with water, and then washing it thoroughly with water to remove all heterogeneous matters.

^a Medico-Chirurg. Transacts. vol. iii.

^b Ann. Chim. tom. lvi.

Birdlime thus prepared is greenish, bitter, very tenacious, spinning out into threads when drawn asunder, and smelling somewhat like linseed oil. When a thin layer is spread out on glass and exposed for some time to light and air it dries, turns brown, and is then no longer viscous, even when again wetted, but may be ground to powder. It reddens litmus. When birdlime is heated without addition, it melts into a pasty mass, swells, becomes full of bubbles, smelling like heated oil, and if put upon heated coals, or when red hot, it burns with much flame and dense black smoke. It continues to burn when once lit, till it is entirely reduced to an ash, which is white and very alkaline.

Water boiled upon birdlime has little or no action upon it except to render it rather more fluid, and to dissolve out a portion of acid (which is shewn by the water reddening litmus) and a little mucilage and extract.

But caustic potash acts very powerfully upon birdlime. A strong lye of potash boiled with birdlime forms a white magma which on evaporation turns brown, hardens, and acquires the smell and taste of soap. This soap dissolves in alcohol and water, and is decomposed by acids like the common soaps.

Sulphuric acid blackens and carbonizes birdlime, and on adding lime the smell of vinegar is perceived.

Nitric acid heated on birdlime converts it to a hard brittle mass, which when treated with more of the same acid, is partly changed to oxalic and malic acid, and partly to a yellow wax-like resin, soluble in potash and in alcohol.

Birdlime long shaken in concentrated oxymuriatic acid becomes white, loses its viscosity and is broken into hard compact masses, still enclosing a portion of the unchanged birdlime.

Acetous acid softens birdlime and dissolves a portion. Carbonat of potash does not disturb this solution, and when evaporated to dryness it leaves a residue resembling the resins, but which cannot be perfectly dried.

Boiling alcohol dissolves birdlime. The solution is of a clear yellow when hot, but becomes turbid on cooling, and deposits a yellow matter like wax, whilst the clear liquor remains bitter, nauseous, acid, and leaves a kind of resin when evaporated.

Sulphuric ether totally dissolves birdlime, and with more ease than any other reagent. The solution is greenish, yellow and acid. When much water is added, an oil separates and comes up to the surface, which much resembles linseed oil, and will form a compound like plaster when boiled with litharge. The ethereal solu-

tion of birdlime when evaporated leaves a yellow soft matter like wax. All these facts shew the analogy of birdlime with oily or resinous substances, and its entire difference from vegetable gluten.

BISMUTH.

1. Native. Its primitive form, according to Hauy is the regular octohedron; and the only other crystal that he mentions as belonging to this species, is an acute rhomboid, the alternate angles of which are 60° and 120° .

Besides the three species of ores described in the article Bismuth in this Dictionary, there are certain natural mixtures probably, rather than combinations, of metals in which bismuth is the predominating ingredient, and which therefore may be mentioned here.

1. Bismuth with Copper and Sulphur.

This substance was discovered by Selb in the cobalt mine of Neugluck, in the district of Furstenberg. Its colour is steel-grey, by exposure to the air becoming bluish and reddish; has a slightly metallic lustre, a fine grained fracture, is soft and semi-ductile. According to Klaproth, it is composed of

47.24 Bismuth

34.66 Copper

12.58 Sulphur

94.48

2. Argentiferous Bismuth.

Its colour is a pale lead-grey becoming darker on exposure to the air; it is generally disseminated, rarely in mass. It melts easily before the blowpipe. It occurs at Schatzlach, in the Black forest, and according to Klaproth, is composed of the following ingredients.

33. Lead

27. Bismuth

15. Silver

4.3 Iron

0.9 Copper

16.3 Sulphur

96.5

3. Nadelierz.

Its colour is steel grey verging more or less to copper red, but generally is dull, and superficially yellow or green from decomposition. It occurs disseminated, or crystallized in striated acicular hexahedral prisms, often curved, sometimes articulated, and always implanted. Its longitudinal fracture is lamellar with a splendid metallic lustre. It is soft, semiductile, and its specific gr. is about 6.1. It occurs in Siberia in white quartz mixed with native gold.

It has been analyzed by M. John, and appears to consist of

43.2	Bismuth
24.32	Lead
12.1	Copper
1.58	Nickel
1.32	Tellurium
11.58	Sulphur

94.1

Pr. Berzelius^a states the composition of the oxyd of bismuth from the very accurate experiments of M. Largerhjelm, to be

Bismuth	. 90.803	—	100.00
Oxygen	. 9.197	—	10.13
	100.000		110.13

Sub-sulphat of Bismuth. Some of this salt was prepared by decomposing the neutral sulphat by water. The sub-sulphat, thus precipitated, being washed and dried on very hot sand, 100 parts of the dried salt were strongly ignited in a platina crucible till no further loss of weight was perceived. The loss was 14.5 and consisted of sulphureous acid and oxygen, leaving 85.5 of oxyd of bismuth. The 14.5 sulphuric acid thus decomposed, and the 85.5 of oxyd each contain 8.66 parts of oxygen.

The Neutral Sulphat of Bismuth is composed of so much acid as contains three times as much oxygen as that of the base with which it is saturated. This would give the elements of this salt to be 14.5 sulphuric acid and $\frac{85.5}{3} = 28.5$ oxyd, or

Sulphuric Acid	. . 33.7
Oxyd of Bismuth	. . 66.3
	100.0

Nitrat of Bismuth. 10 parts of this salt, crystallized, reduced to powder, and dried in the air, were distilled in a small retort. The nitrous acid that passed over was colourless and not fuming, which shews the presence of much water of crystallization. In the retort were left 4.88 parts of oxyd, so that the crystallized nitrat well dried contains

Nitric acid and water	. . 51.2
Oxyd of bismuth	. . 48.8
	100.0

Sulphuret of Bismuth. This compound

^a Ann. Chim. tom. 82. p. 121 and 241.

consists, according to Vauquelin, of 68.25 of bismuth, and 31.75 sulphur, as mentioned in the article *Sulphuret* in this appendix.

BITTERS PATH, or MAGNESIAN CARBONATE OF LIME.

The primitive crystalline form of this substance is considered by M. Haüy as precisely the same with that of calcareous spar; hence he considers the magnesia contained in it as purely accidental, and on this account denominates it *Chaux carbonatée magnésifère*. Dr. Wollaston however has shown that the obtuse angle in the primitive rhomboid of calcareous spar measures $105^{\circ}.5'$, while the same in the primitive rhomboid of bitterspath is at least $106^{\circ}.15'$. The two substances may therefore be regarded as specifically distinct.

BLOOD.

Several very important additions have been made to the chemical knowledge of this most interesting of all the animal fluids. We shall give a short abstract of them.

It was stated as a discovery of Fourcroy and Vauquelin, and confirmed by Parmentier and Deyeux, that the serum contains *Gelatine*, and the particulars were mentioned under the article BLOOD, (*Ch. Dict. vol. 1.*) It has since been very amply proved however that this is a mistake, and that the substance contained in serum, uncoagulated by heat, is not gelatine, though on evaporation to dryness it leaves a stiff transparent mass. Dr. Bostock, who first detected the mistake of these eminent chemists on this subject, has the following remarks.^b

He defines *Gelatine* or *Jelly* to be an animal substance which is liquefied by heat, becomes concrete by cold, and with tan forms a compound insoluble in water. After the serum has been partially coagulated by heat, the liquid that remains, (or the *Serosity*,) yields a sensible precipitate when heated with corrosive sublimate, shewing the presence of some albumen which has escaped the first coagulation by heat, after which the liquid may be evaporated nearly to dryness without shewing any degree of gelatinization on cooling, and without being at all altered by infusion of tan; both of which circumstances prove the absence of gelatine. This was further shewn by the addition of a small portion of gelatine to the serosity, which now gave all the characters belonging to this animal principle. Dr. B. however does not consider the whole of the animal matter in the serosity to be albumen that has escaped coagulation, but supposes a

^b Medico-Chirurgical Transact. vol. i. and ii.

portion to be similar to animal *mucus*, though its nature is obscure. This matter forms about 2 per cent. of the serosity, and the remaining solid contents amount to about 10 per cent. more.

Dr. Marcet^c has given some valuable experiments on the contents of the serosity as compared with those of other watery fluids of the animal body, whether natural or morbid. The specific gravity of serum varies remarkably, being found from 1024.5 to 1032.5. On a careful analysis he gives the following as the constituent parts of serum, the dry contents being all thoroughly desiccated in a sand heat without charring or decomposition :

Water	900.00
Albumen	86.80
Muco-extractive matter	4.00
Muriat of soda with a little muriat of potash	6.60
Sub-carbonat of soda	1.65
Sulphat of potash	0.35
Phosphats of lime, iron, and magnesia	0.60
	1000.00

It will be seen therefore that serum contains a tenth of its weight of solid contents, nine-tenths of which are animal matter, and the rest saline.

Dr. M. agrees with Dr. Bostock in asserting the total absence of true gelatine in serum, but allows a kind of muco-extractive matter, which is distinguished by being incoagulable, and soluble in water and other menstrua. The little albumen with which it remains combined after the serum has been heated is entirely separable by being boiled with corrosive sublimate.

Since the publication of Dr. Bostock's paper Mr. W. Brande has made some chemical researches on the blood,^d in which he has very happily applied the galvanic influence, in order to detect the real nature of the animal matter that remains in serosity after the coagulation of the bulk of the albumen by a boiling heat. One ounce of pure serum was diluted with water, the conductors from a battery of thirty pairs of four inch plates were immersed in this solution at a distance of two inches from each other, and the whole of the albumen coagulated in contact with the negative wire in three hours and a half, the coagulum being occasionally removed. A similar effect was produced in the serosity after the greater part

of the albumen had been coagulated by heat; the fluid was then exposed to the galvanic action, and albumen coagulated at the negative wire. In both cases the fluid, evaporated after the galvanic action was over, gave no change on adding infusion of galls, nor afforded any gelatine when dry. On the other hand, some solution of isinglass was added to serum, and the galvanic action applied, but after all coagulation had ceased, the liquid still gave a copious precipitate by galls. Hence it appears that galvanic electricity has no effect in separating gelatine from its solution, though it totally precipitates albumen. It was also found that heating serum with the addition of a little muriatic acid, as effectually coagulates the whole of the albumen as is done by the agency of galvanism.

Mr. Brande has given some additional facts relative to the properties of the colouring matter of the blood, which (as well as those of professor Berzelius, to be presently mentioned) throw much uncertainty on the hypothesis of Fourcroy and Vauquelin, that the colour is given by a sub-phosphat of iron dissolved in serum, and indeed make it doubtful whether this metal is at all concerned in giving to blood its deep and beautiful colour. The colouring matter was generally obtained by stirring venous blood with a stick as soon as drawn; the fibrin collects at the end of the stick, and the colouring matter is diffused through the serum, from which it gradually subsides, and may therefore be collected in a very condensed form though still mixed with serum. This substance readily dissolves in water, making a bright red solution when filtrated, which however becomes brown and separates by a boiling heat into a clear colourless water and a brown sediment. Muriatic acid, poured upon the dense colouring matter above described, renders one portion brown and insoluble, but dissolves the other portion into a liquid, which when filtrated is a dark crimson in reflected light, but greenish in transmitted light. The colour is not altered by long exposure to light, nor by a boiling heat, nor materially by alkalies, nor by galls. The dilute sulphuric acid extracts the colouring matter as well as the muriatic. Both these solutions may also be made by digesting at a heat of 150° to 200° some pieces of the common coagulum of blood with the acid employed. If muriatic acid, it may be diluted with an equal quantity of water; and if sulphuric,

^c Medico-Chirurgical Transactions, vol. 2.

^d Phil. Trans. for 1812.

with eight or ten parts of water. The nitric acid on the other hand much impairs the fine colour and gives it a shade of brown. The acetic acid acts as the muriatic, but with still more distinction between the effect of reflected and transmitted light. With the tartaric acid the solution inclines to scarlet.

Both the caustic and carbonated alkalies form deep red solutions of this colouring matter, which are very permanent. Soda gives a colour more inclining to a crimson, and ammonia still more. When these solutions are supersaturated with nitric acid the colour passes into bright yellow.

The author then endeavoured to combine this colour with some of the common mordants. Alumine would not answer, for though it extracted the colour pretty well, it became brown instead of retaining its original red. The solutions of tin succeeded scarcely better. Those of mercury answered the best. When corrosive sublimate is added to the aqueous solution of the condensed colouring matter, its tint is instantly brightened, and it becomes slightly turbid from the deposition of a little albumen. If this be immediately filtered, the clear liquor gradually deposits a deep red insoluble precipitate which carries down the whole of the colour. Woollen cloth first steeped in corrosive sublimate and then in a watery solution of the colouring matter of blood, acquires a permanent red tinge unalterable by soap, which possibly may be of use in dyeing.

We shall conclude this article with a very short abstract of the most original parts, in an elaborate analysis of blood made by professor Berzelius, being one of a series of investigations on animal fluids, first published in this country in the *Medico-Chirurgical Transactions*, vol. 3.

The blood selected for experiment was that of the ox.

Blood, he observes, may be regarded as a liquid holding a colouring matter suspended in it, but not dissolved.

The only practicable way of separating the constituent parts of blood is that of coagulation, as usually employed, though this is imperfect, as much of the serum remains attached to the red globule in the coagulum.

The crassamentum contains the fibrin and the colouring matter, which are separable by washing, in the way often described.

Fibrin. No part of this is soluble in cold water, but a portion is extracted by long boiling, which when the liquor is evaporated

gives a white, dry, friable residue, soluble in cold water, and of an agreeable taste like broth. Fibrin, when long boiled, loses the property of being soluble in acetic acid.

Alcohol digested with fibrin changes it to an adipoceros or fatty matter, soluble in the alcohol, and separable by water. This fatty matter is formed in the process, and does not exist as such in the recent fibrin.

Ether has a similar effect with alcohol, and the fatty matter is more abundant and more nauseous.

Concentrated acetic acid immediately softens fibrin, renders it transparent, and when heated dissolves it into a tremulous jelly, which is soluble in warm water. When this solution is evaporated to dryness it retains sufficient acid to redden litmus, but will not redissolve without more acid. Sulphuric, nitric, and muriatic acids, give a precipitate with this solution composed of fibrin and the acid employed, which when washed with water loses a part of the acid, and the remainder dissolves in more water. More acid will again give a precipitate with the latter solution, so that fibrin with a certain portion of acid is soluble in water, and with an excess of the same acid becomes insoluble. Alkalies also give a precipitate with the solution of fibrin in acids, and an excess of alkali redissolves it.

Weak muriatic acid, digested with fibrin, hardens and shrinks it, and long boiling with water at last converts this to a soluble gelatinous mass. Some azotic gas is given out. This solution is again precipitated by an excess of the acid.

Concentrated muriatic acid decomposes fibrin when boiled upon it, and gives a violet coloured solution.

Sulphuric acid, when diluted, has a similar effect on fibrin with muriatic acid; and like this, produces two compounds with it, one insoluble, in which the acid is in excess; and the other, where the acid is scarcely predominant, soluble in water. Nitric acid of 1.25 sp. gr. digested with fibrin turns it yellow, and forms a small quantity of fat on the surface. Pure azotic gas is given out. After a day's digestion the fibrin becomes a yellow powder, which turns to orange by washing, and is less acid, but still remains enough to redden litmus. This substance, first discovered by Fourcroy and Vauquelin, was supposed by them to be a new acid, and called by them *Acide Jaune*, but professor Berzelius considers it as a compound of fibrin, with nitric or nitrous

acid, and with the *malic* acid formed by the action of the nitric acid on the fibrin. The latter acid is thus detected: the yellow powder above mentioned is first boiled with alcohol, which when cool deposits an adipoceros matter, that is to be removed. The liquor is then digested with water and chalk, which slowly dissolves the earth with some effervescence, and this solution, made clear by filtration, is evaporated to a syrupy consistence, and then mixed with alcohol, which dissolves one part and precipitates another. The precipitate has all the characters of *malat of lime*. The part dissolved in the alcohol is *nitrat of lime*.

Caustic alkali first enlarges, then dissolves fibrin forming a yellowish green liquor. The fibrin is somewhat changed by this process, for acetic acid which separates it from the alkaline solution will now no longer redissolve it. But nothing like a true soap is produced by the action of alkali on fibrin.

The Colouring Matter. To obtain this in tolerable purity the crassamentum of blood was cut into thin slices, and dried on sheets of blotting paper. This was rubbed with water which extracted so much as to acquire a very deep brown colour. This solution was coagulated by heat, forming a dark brown matter which when dried under a press was a black hard substance, with a vitreous fracture, and was considered as the colouring matter.

The properties of this matter are so nearly the same as those of fibrin that we shall not enumerate them. They are distinguished chiefly by the difference in colour, and by the fibrin coagulating spontaneously as soon as drawn, whereas the colouring matter requires to be heated. Albumen has the same general properties and habitudes with acids, so that the greatest chemical difference between fibrin, albumen, and colouring matter, consists in the colour of the latter, and this leads to the still problematical question as to the *cause of the Colour of the Blood*.

The author asserts (contrary however to the experiments of some chemists) that oxyd of iron, which is found in a notable quantity in the ashes of the colouring matter, is not contained (or at least only in an infinitely small portion) in the ashes of fibrin or albumen.

We have already stated in our former article the opinion of Fourcroy and Vauquelin on the mode in which the iron that they suppose colours the blood exists in that fluid, being a red sub-phosphat dissolved in albumen. Parmentier and Deyeux suppose that the naked

alkali of blood is the great agent that holds in solution this colouring metal. But our author conceives that all are mistaken, and that the mode in which the iron is combined, is totally unknown, though he attributes the colour to the presence of this metal, but not as an oxyd united to any acid.

By incineration of 20 grammes of colouring matter till the charcoal was completely destroyed, he obtained 0.25 gramme of a yellowish-red ash. 100 parts of this ash accurately analyzed, gave the following results, viz.

Oxyd of iron	50.0
Sub-phosphat of iron	7.5
Phosphat of lime with a } little magnesia	6.0
Pure lime	20.0
Carbonic acid and loss	16.5
	100.0

But the phosphat of iron was probably not contained as such in the colouring matter, but was produced by the process of the analysis. The chief arguments which the author brings against Messrs. Fourcroy and Vauquelin's hypothesis, are the want of any precipitate when the prussiates, gallic acid, barytic water, phosphoric acid, and sulphuret of potash are added to the colouring matter, all of which would act differently on any solution of a *salt* of iron, such as the sub-phosphat is. He also shews (and this is in direct opposition to the above French chemists) that the sub-phosphat artificially prepared and mixed with serum, does *not* produce any thing at all resembling the colouring matter of blood, but only a rusty coloured liquid, from which the colouring matter may be totally separated by mere filtration. It is true that many of the oxyds of iron are largely soluble in serum, but these solutions easily shew the presence of this metal with those tests that fail to discover it in the blood itself. The prussiates alone do not disturb the solution of iron in albumen, as the solvent of the metal is not an acid.

Of the Serum, Albumen, and Salts of the Blood.

The chemical properties of albumen are so nearly the same as those of fibrin, that the same description will serve for both. The ash of burnt albumen is white and perfectly free from iron. It chiefly consists of phosphat and carbonat of lime, with a little magnesia.

Human blood differs but little from that of the ox in its chemical analysis. The serum of

human blood is thus composed according to our author, viz.

Water	905.0
Albumen	80.0
Substances soluble in alcohol, viz. } Muriat of potash and soda . . 6. }	10.0
Lactate of soda with animal matter 4. }	
Substances soluble only in water, viz. } Soda, phosphat of soda, and a little } animal matter }	4.1
	999.1

This analysis has a very satisfactory agreement with that of Dr. Marcet just stated, considering the varying nature of the blood and the difficulties of analysis. There is one substance however now for the first time introduced by Professor Berzelius as a component part of this, and indeed of most other animal fluids, which is the *Lactate of Soda*.

The *Lactic Acid* was first discovered by Scheele, and by him was considered as having sufficiently distinct properties to be entitled to a place among the list of particular acids. Latterly however some eminent French chemists have sought to prove that the supposed Lactic acid is only a combination of acetous acid with some animal matter. But it appears that the only proof of the identity of this with the acetous acid has been the production of vinegar when the lactic acid is distilled with the sulphuric, in which case there condenses in the receiver a mixture of sulphureous and empyreumatic acetous acid, from which the latter is obtained pure by subsequent rectification. To this Pr. Berzelius objects that by a parity of reasoning all the vegetable acids hitherto considered as distinct species might be reckoned as acetous, modified by some peculiar substance, since they all yield acetous acid when distilled with the sulphuric.

Many chemists, he observes, have noticed in their analysis of animal fluids that the alcoholic solution when evaporated leaves a yellow deliquescent extractive mass. This contains *Lactate of Soda* and an animal matter which always accompanies it, but may be separated by tannin. To analyze it, dissolve the whole in alcohol, add a mixture of sulphuric acid diluted with much alcohol as long as there appears any precipitate, which is sulphat of soda. Digest the spirituous solution (which often contains the sulphuric, muriatic, lactic and phosphoric acids)

with carbonat of lead, and all these acids will unite with the oxyd of lead; but of these the lactate alone will be soluble in alcohol which is therefore to be added. Then decant the alcoholic solution, separate the lead by a current of sulphuretted hydrogen gas, and the clear liquor will contain the lactic acid. This may be further evaporated, but cannot be crystallized.

BORACITE.

The primitive form of this substance is a cube; and it is remarkable that in the secondary crystals those parts which correspond to the opposite solid angles of the primitive nucleus are destitute of that symmetry which prevails in most crystalline bodies; in this respect however they are analogous to the secondary crystals of tourmaline, and, like these, are electric by heat, and exhibit on the opposite dissimilar faces, at one extremity positive, and at the other negative electricity.

BORACIC ACID. BORACIUM.

The powerful deoxygenating energy of Potassium has been very successfully applied to the discovery of the basis of the boracic acid, the decomposition of which had frequently been attempted before without success. The fact of the production of a new olive coloured substance from boracic acid on the negative surface of a powerful galvanic pile was indeed the first approach to the knowledge of the base of this acid made by Sir H. Davy; and the same chemist some time after announced the production of a black substance, on igniting boracic acid in a gold tube with potassium. Since this time more numerous and very similar experiments were carried on nearly at the same period both in this country and by Messrs. Gay Lussac and Thenard,^c from which the following properties have been made out of the base of this acid, to which the French chemists have given the name of *Bore*, and Sir H. Davy, *Boracium*.

Boracium is thus prepared. Take some pure boracic acid, which is done by decomposing borax, either by sulphuric or muriatic acid, but if the sulphuric is used, the precipitated boracic acid must be fused for a few minutes in a Hessian crucible to expell some of the sulphuric acid that adheres to it. A platina crucible will not answer, as it would be soon spoilt by the operation. If muriatic acid is employed, the boracic is pure at first, and then crystallizes in very small scales, whereas when it contains a little of the sulphuric, the scales are much

^a Phil. Trans. for 1808.

^b Ibid for 1809.

^c Recherches, tom. 1.

larger and broader. Put equal parts of the boracic acid reduced to fine powder, and of potassium into a small tube either of coated glass or of brass, copper, or iron, and adapt a narrow glass tube dipping under mercury to keep out the external air. Then gradually heat the ingredients in a small furnace till the tube becomes of a low red, and keep it thus for a few minutes and the operation is finished. Scarcely any gas is expelled in the process, but as soon as the heat reaches a certain point, a vivid inflammation takes place, which melts the glass tube if more than a few grains of each material are used; so that on this account a copper tube is preferable. The product of this experiment is an olive-coloured earthy looking matter, which when boiled for a few minutes partly dissolves in water leaving behind a dark olive-coloured powder which should be welledulcorated with sufficient muriatic acid to neutralize the excess of alkali, and dried. The solution contains borat of potash and an excess of caustic potash; the olive powder is the *Boracium*. With equal parts of boracic acid and potassium there is always a great proportion of the acid undecomposed, for Sir H. Davy finds that 20 grains of potassium are required to decompose 8 grains of the acid, but no inconvenience arises from this deficiency of potassium besides the loss of a little boracic acid, as the boracium is completely separated by water from the potash and borat of potash.

Boracium is an opaque friable insipid powder, neither acid nor alkaline. It neither melts nor volatilizes when strongly heated in close vessels but only becomes denser. It is insoluble in water, alcohol, ether or oils. When it is gently heated in a retort filled with oxygen gas, it kindles and burns with most vivid scintillations and a brilliant light. A sublimate rises from it, which is boracic acid, and a coating of the same acid also vitrifies around the burning mass, which, after a while, extinguishes the combustion before the mass is entirely converted to acid; and hence it remains black, and only partly soluble in water, the insoluble portion being combustible as before. Boracium also burns in common air when heated red-hot, and the combustion is only partial for the same cause. When boracium is placed in contact with oxymuriatic gas at a common temperature, it instantly takes fire and burns with a brilliant white light, and a white sublimate coats the vessel, which when moistened yields boracic acid. When thrown into nitric acid, boracium renders it bright red, and when heated, there is much effervescence of nitrous gas, the boracium dis-

appears and the acid liquor contains boracic acid. Boracium heated with most neutral salts deprives their acids of the oxygen which they contain. Thus when calcined in close vessels with sulphat or sulphite of soda, borat of soda and sulphur are formed: when heated with nitre or oxymuriat of potash, much deflagration ensues, and borat of potash is produced. It also decomposes carbonat of soda in a high temperature, forming borat of soda and charcoal.

There is some difficulty in fixing with any accuracy the proportions of boracium and oxygen in boracic acid; for in any common mode of burning these two substances, the operator is obliged to interpose several lixiviations of the product on account of the imperfect combustion for the reason already described. The oxygenation by nitric acid answers better, for when boracium is boiled for some time in this acid, it is totally changed to boracic acid, the weight of which after boiling down and ignition indicates that this acid contains one third of oxygen and two-thirds of base. These proportions however, which are those of the French chemists, do not even approach to those of Sir H. Davy, who estimates about two parts of oxygen to one of base. As the olive-coloured substance obtained by potassium and boracic acid does not conduct electricity, and combines with alkalies, it is conjectured by this chemist to be not the pure base but a primary oxyd; and when some of it is heated strongly with potassium and iron filings, a dark metalline mass is formed which conducts electricity, slightly effervesces in water, and by solution in nitric acid gives oxyd of iron and boracic acid.

If this conjecture be well founded, there would appear to be three substances here concerned, namely: the base of boracic acid or *Boracium* which is still not known: the *Olive oxyd* above described and improperly called boracium; and the boracic acid. From some appearances in one of the experiments it appears also not improbable that there is a blackish oxyd containing more oxygen than the olive matter and intermediate therefore between this and boracic acid.

BRAUNSPATH.

This substance from the supposed identity of its primitive crystalline form is considered by Hauy as carbonate of lime, with a variable and accidental proportion of carbonate of iron, (*Chaux carbonatée ferrifère*). But Dr. Wollaston has shown that the obtuse angle of its primitive rhomboid measures $107^{\circ}.0'$, instead of $105^{\circ}.5'$ that of calcareous spar.

BRONZITE, see DIALLAGE.

C

CALCIUM. BASE OF LIME.

The same evidence for the existence of a Base of Lime is obtained both by analogy and by direct experiment as for the base of Barytes or Barium, and the mode of obtaining Calcium is the same as that described for *Barium*, substituting pure white marble or chalk to the carbonat of barytes. Calcium has been procured in such minute quantities that but little is known about it, except that it is a bright white metal which produces lime when oxydated.^a

Lime appears to consist of about 40 of calcium to 15 oxygen. When lime is moistened with water or slacked, and dried at a heat short of redness, it retains a portion of water and is then properly a hydrat of lime, and it consists of about 17 of water to 55 of lime. A red heat again expells all the water, so that lime does not retain water so obstinately as the fixed alkalies, which remain hydrats even when fused by themselves at a red heat.

CAMPHOR. CAMPHORIC ACID.

M. Bucholz^b has made several experiments on this acid, particularly with a view of comparing its properties with those of the benzoic acid.

He prepares this acid in the following way. Two ounces of camphor are mixed with a pound and a half of nitric acid of 1.25 sp. gr. and half a pound of the same acid of 1.55 sp. gr.: half the acid is distilled over with a gentle heat and then returned on the materials in the retort and again distilled as before, and this is repeated three times. After the second distillation no more of the camphor appears than a little oil of camphor floating on the acid. When the process is concluded, the camphoric acid is found above the acid in the form of a white butyraceous matter. This is separated from the acid by a glass funnel, and is further freed from the adhering acid by being dissolved in boiling water, when it crystallizes pure on cooling. From two ounces of camphor about five drams of the crystallized acid are obtained, besides a portion which may be washed away by the water employed to separate the adhering acid. Care must be taken not to urge the distillation of the nitric acid too quickly, as it would then decompose the camphor instead of acidifying it; and this is marked by a brown colour in the residue.

The camphoric acid separates from its so-

lution in hot water in feathery crystals like those of muriated ammonia.

Camphoric acid requires for its solution 100 parts of cold water, but only 11 parts of boiling water. It dissolves in its own weight of alcohol at a common temperature, but in every proportion when boiling, forming a liquid mass which solidifies on cooling, if the acid is in large proportion.

Camphorat of Lime. To 50 grains of camphoric acid in 3 ounces of water, carbonat of lime in powder was added gradually. The effervescence ceased when 30 grains of the carbonat had been added, but it still strongly reddened litmus, which shews the existence of a camphorat of lime with excess of acid. When this solution is saturated with lime and much reduced by evaporation, it crystallizes, but not in very defined crystals. The taste of this solution is neither salt nor bitter, but somewhat acerb, and leaving a taste of lime, so that this crystallized salt is probably with an excess of base. This salt requires only five parts of cold water to be dissolved.

Camphorat of Potash. When the saturated solution is brought to a syrupy consistence and left to evaporate spontaneously, small granular crystals are formed, which, when warmed, again liquefy.

In all the above described properties the camphoric acid differs very sensibly from the benzoic.

CAMPHOR. A singular combination of this substance and *Benzoic acid* is described under this latter article in the Appendix.

Some further observations on Kind's artificial camphor produced from muriatic acid and oil of turpentine have been made by Thenard.^c The original experiments of Kind have been already described (*Chem. Dict. art. Camphor*) that of Thenard, which agrees most accurately with the other, is as follows: A hundred grammes of rectified oil of turpentine were put into a vessel surrounded with a freezing mixture of ice and salt, and muriatic acid gas introduced, of which 30 grammes were absorbed. No gas was given out except muriatic, when the oil of turpentine began to be saturated. The mixture assumed a soft consistence and became a crystalline mass; and after draining three days, 20 grammes of a liquid separated, leaving nearly 110 grammes of the peculiar white granulated

^a Davy.

^b Ann. Chim. tom. lxxxiv. p. 301.

^c Mem. de Arœuil, tom. ii. p. 29.

substance, which is the *artificial camphor*. When this is washed by a weak alkaline solution, all acidity sensible to the taste and to test liquors is lost; yet when it is sublimed or passed through a red-hot earthen tube, much muriatic acid appears; and also when nitric acid is boiled upon it, much nitro-muriatic acid is given out. The fluid portion that drained from the mass had a similar composition and contained much muriatic acid. These drainings are black if common oil of turpentine be used.

With regard to the nature of this singular substance M. Thenard denies the probability of any decomposition of the oil, but considers it as a mere compound of muriatic acid and oil, in which the union is so intimate, that all the sensible properties of an acid are lost.

CANTHARIDES. SPANISH FLY. The well known acrimony of this insect shewn in its powerful blistering quality, has often made it the subject of chemical examination, chiefly with a view of separating the principle in which this acrimony resides. M. Robiquet^a gives the following method of obtaining it. Boil any quantity of bruised cantharides in distilled water, strain off the reddish-brown decoction, and add more water to the residue to extract all that is soluble. Mix and evaporate all the decoctions in a moderate heat to the consistence of a soft extract, and digest this repeatedly in boiling alcohol till the soluble part is taken up, neglecting the residue, which is a mild inert matter. This alcoholic solution is yellow and excessively acrid. Evaporate this nearly to dryness, then put the extract which is left, into a phial with cold sulphuric ether, and frequently shake them. In a day or two the ether becomes of a pale yellow. Pour off the clear ethereal solution and let it evaporate totally in the air. It will deposit scales resembling mica, mixed with a little oil which alcohol will remove. These scales are intensely acrid, and seem to contain nearly all the blistering properties of the fly itself. The smallest visible portion of them dissolved in oil when applied to the skin, will raise a blister in an hour or two.

The residue of the cantharides in substance, after the decoction in water is poured off, will give a tincture to alcohol, which when evaporated leaves a green unirritating oil.

CARBON. CARBONIC ACID. DIAMOND.

We have to give a short account of two or three very important series of experiments on the combustion of different species of charcoal, on the proportions of base and oxygen in carbo-

nic acid, and on the supposed identity of the diamond with charcoal.

The first to be mentioned are those of Messrs. Allen and Pepys.^b

The object of these accurate chemists was to consume certain known quantities of diamond and other carbonaceous substances in oxygen gas and thereby to determine the quantity of carbonic acid produced. The apparatus consisted of a platina tube, holding a platina tray that contained the substance to be burned, and was itself strongly heated by a furnace into which the tube was inserted. The tube was connected with and between two mercurial gasometers, and these were so contrived that oxygen gas could be transmitted alternately from one gasometer to the other, each time passing through the ignited platina tube that contained the substance to be examined.

The oxygen gas was prepared from oxymuriat of potash, and used a few hours after it had been procured; its purity being first ascertained by the eudiometrical test of sulphat of iron holding nitrous gas in solution, to absorb the oxygen of the portion analyzed, followed by simple sulphat of iron to absorb any nitrous gas that might have been expelled from the first liquid.

The charcoals which were made the subject of the first experiments were prepared directly from different kinds of wood, each of which was put into a small crucible and covered with sand, and was gradually ignited and finally kept for about 40 minutes at a white heat. In this way the woods employed yielded from 15 to 20 per cent. of their weight of dry charcoal. As it was found that dry charcoal when exposed to the air increased from 10 to about 20 per cent. of its weight by the absorption of moisture, the specimens employed for the experiments were again heated immediately before the experiment and weighed whilst still warm.

The gasses were all estimated at the same temperature of 60°, and at 30° inches barometer. The correction for expansion by heat was taken from the datum of Gay Lussac, who asserts, that air expands 0.00208, or $\frac{1}{480}$ part of its bulk, for every degree of Fahrenheit from 32° to 212°. which very nearly agrees with Mr. Dalton's estimation. The quantity of gas to be estimated was therefore divided by 480, and the quotient multiplied by the degrees of difference from 60° for the correction for temperature.

A preliminary object was to estimate the exact weight of oxygen and carbonic acid gas.

^a Ann. Chim. tom. 76.

^b Phil. Trans. for 1807.

The carbonic acid gas was obtained from marble and dilute sulphuric acid, and was of such purity that 99 parts out of 100 were absorbed by lime water.

A glass globe previously exhausted of air, was filled with 21 cubic inches of the carbonic acid gas in the state in which it was procured, which weighed 10.2 grains at 44° therm. and 29.86 bar.

These 21. cubic inches equalled 21.58 at mean pressure and temperature, and hence 100. cubic inches of carbonic acid gas weigh under these circumstances 47.26 grains.

Oxygen gas was then obtained from oxymuriat of potash over mercury, which when analyzed by the nitrous sulphat of iron, left an unabsorbed residue of only 2 in 100. The glass globe holding 21 cubic inches was filled with this oxygen under the same pressure and temperature, which weighed 7.3 grains. Hence the weight of 100 cubic inches of oxygen of 98 per cent. purity weigh at 60° ther. and 30° bar. 33.82 grains.

The experimenters then ascertained by trials on known mixtures of carbonic acid gas and oxygen, that lime water would extract the whole of the carbonic acid from such a mixture.

The experiments on the combustion of charcoal were then performed by passing oxygen from one gasometer to the other through the platina tube containing the charcoal already heated to redness. The results of each experiment were as follows:

1. Four grains of Box-wood charcoal were all consumed except 0.02 grains of ash, and produced 13.76 grains of carbonic acid, which occupied exactly the same volume as the oxygen of which it was composed. No flash of light was observed during the combustion, whence the absence of hydrogen was inferred. The 3.98 grains of pure charcoal took 9.85 grains of oxygen for its combustion, which should therefore have produced 13.83 grains of carbonic acid. The actual quantity of carbonic acid obtained was 13.76 grains, making a difference of only .07. It may be observed that on analyzing the entire gas at the end of the experiment, after removing the carbonic acid gas by lime-water, and the oxygen by nitrous sulphat of iron, exactly the same proportion of unabsorbed residue was left as the oxygen itself furnished before the experiment, whence it was inferred by the experimenters (and with great probability) that no gas whatever was furnished by the combustion of the charcoal except car-

bonic acid. This residue however was not actually analyzed, but was taken as azote.

Calculating from the quantity of oxygen and charcoal actually consumed in this experiment, the carbonic acid should be 13.83 grains, which would give 28.77 grains of charcoal in 100 grains of carbonic acid.

Calculating from the volume of carbonic acid actually produced, which was 29.13 cubic inches, its weight (from the data originally found) must be 13.76 grains, which contained the 3.98 grains of charcoal consumed, and hence 100 grains of carbonic acid must contain 28.92 grains of charcoal.

2. The second experiment was on the combustion of transparent Brazilian diamond. This was performed precisely in the same manner as the last. The oxygen gas was repeatedly passed over the red-hot diamonds for ten minutes. The combustion did not raise the heat to whiteness as with charcoal, as it went on more slowly. The portions of diamond that remained unconsumed at the end of the experiment were all reduced to an opaque white substance resembling enamel. There was no discolouration of the platina vessel nor any ash whatever. Out of 3.95 grains of diamonds employed, 2.49 grains were consumed. The results will be given presently in a tabular form. No water whatever was condensed in the gasometer after the experiment.

3. A second experiment was made on 4.01 grains of diamonds. In a quarter of an hour they were totally consumed, and not a vestige left.

4. The next experiment was made on Welch stone-coal or culm, used by maltsters, which contains little or no maltha, and burns without flame. This was previously strongly heated under sand. The oxygen was passed over four grains of it in the platina tube for ten minutes, and the whole was consumed except half a grain of residue.

5. Plumbago was next tried. In a quarter of an hour 4 grains of it were consumed except .2 of a grain of oxyd of iron.

6. Muscular fibre distilled in a coated glass retort, left a black shining animal charcoal, 4 grains of which were put into the platina tube and heated. The first time the oxygen gas passed over it, a lambent flame filled the whole of the glass tube, connecting the platina tube with the gasometer. After the experiment, a minute portion of charcoal remained, and a quantity of saline matter adhered to it so firmly,

that it became impossible to ascertain the carbon consumed.

7. Some of the animal charcoal was heated to redness under sand for an hour, after which 4 grains of it were put into the platina tube. On first passing the oxygen over it, flashes ran along the glass tube, and the whole gas became cloudy. The platina tube after the experiment had lost 3.2 grains, but this loss was not wholly carbon, as some of the salts contained in the animal charcoal might have been volatilized by the heat, and in fact the inner surface of the gasometers was slightly covered with an efflorescence. To make this experiment agree with the former ones, it is necessary to suppose half a grain of volatile matter in the 3.2 grains of charcoal.

The results of the above experiments, excluding those on animal charcoal, gave the following weight of carbon in 100 carbonic acid.

	Estimating by Carbonic Acid.	Estimating by Oxygen.
Box-wood Charcoal	28.92	— 28.77
Diamond, 1st expt.	28.95	— 28.81
Diamond, 2d expt.	28.82	— 28.72
Stone Coal	28.20	— 28.27
Plumbago	28.46	— 28.46

The mean of the first column of numbers is 28.67, and of the second 28.60. The authors however mention with great candour, that two experiments with box-wood charcoal gave 29.75 and 30.68 per cent. of carbon; and one experiment with diamond gave 29.96, all of which are rejected from the mean estimate as being inaccurate.

The general inferences from these experiments are, that 100. grains of carbonic acid contain about 28.6 grains of carbon: that well burnt charcoal contains no sensible quantity of hydrogen, but if exposed to the air for a few minutes, it absorbs moisture, which renders the analysis in this state uncertain: and that charcoal cannot with any propriety be considered as oxyd of diamond, since it requires full as much oxygen to be converted into carbonic acid as diamond does.

We may add too that these experiments confirm the fact first observed by Lavoisier, that when oxygen gas is converted into carbonic acid by the combustion of charcoal, no change what-

ever takes place in the volume of the gas, so that in all analyses one measure of pure carbonic acid may be safely assumed as indicating the same measure of oxygen gas.

The above experiments are valuable for the accuracy with which they appear to have been performed, and the fidelity with which the results are related, but two defects have been pointed out. One of them is, that in no instance were any of the gasses stated to have been freed from hygrometric moisture, which defect is particularly to be noticed in the estimation of the carbonic acid gas, since in the experiment by which the weight of this gas was first ascertained, it was procured in the moist way directly from marble and sulphuric acid; but in the subsequent experiments the carbonic acid was formed by ignition of charcoal carefully dried.

The other defect is, that all the gas after combustion was analyzed only by lime-water to absorb the carbonic acid, and by nitrous gas in sulphat of iron to remove the oxygen; the residue unabsorbed by either being assumed as azote without further examination. However, as this unabsorbed residue in every instance almost exactly corresponded with the original azotic impurity of the oxygen employed, this omission is perhaps of less importance than the other.

The next series of experiments on this subject which we shall mention, are those of Theodore de Saussure,* which were conducted with the express view of avoiding certain sources of error presumed in those just related.

The first object was to find the specific gravity of oxygen and carbonic acid. The author gives the weight of a cubic decimetre (61.028 E. cub. inch.) of oxygen gas not freed from hygrometric moisture to be 1.3552 grammes (20.88 Eng. grains) at 12.5° cent. therm. (54.5° Fahr.) and at 0.758 metre pressure (29.843 Eng. inches.)

The weight of the same quantity of moist carbonic acid gas under similar circumstances, is given at 1.8578 grammes (28.6918 Eng. grs.) When these are reduced to English weights and measures, it will be found as follows:

100 cubic inches of undried oxygen at 30° Bar. and 60° Therm.	weigh	grains. 34.003
100 ditto	of undried carbonic acid	46.727

These numbers, it may be remarked by the way, somewhat differ from those of Messrs. Allen and Pepys, who give 33.82 grains for the oxygen, and 47.26 for the carbonic acid.

M. Saussure performed the combustion of the carbonaceous substances in a tubulated receiver of about 5 $\frac{1}{2}$ pints capacity, and ignited them by a burning lens. The charcoal was suspended

* Ann. Chim. tom. 71.

on a platina dish, and a small vessel full of dry muriat of lime previously weighed was placed in the tubulure of the vessel. The receiver was first filled with mercury, which was replaced by oxygen gas extracted from oxymuriat of potash, and another small glass vessel was adopted, in which a portion of the gas could be withdrawn for examination.

The analysis of the gas was performed in the following way. The oxygen was extracted by hydrosulphuret of potash saturated with azotic gas, which was allowed five days for its operation without agitation, and with care to preserve a nearly uniform temperature, that no portion of the azote contained in the eudiometric liquor should be expelled. This method he observes is more exact than Volta's, of detonating the oxygen with hydrogen, when the only impurity mixed with the oxygen is azotic gas; but Volta's is preferable where any carburetted hydrogen is present, as the sulphuretted liquor absorbs a sensible portion of this latter gas.

To separate the carbonic acid gas, the author prefers a small bulk of a very concentrated solution of caustic potash; for he finds by direct experiment that lime-water, or rather the water alone, absorbs a little oxygen by agitation as well as all the carbonic acid gas, when no great proportion of azote is present. Therefore though lime-water will accurately separate the carbonic acid alone from a mixture of this gas with common air, it cannot be depended on to give such exact results with a mixture of carbonic acid and oxygen. Messrs. Allen and Pepys had ascertained the accuracy of lime-water in the former case, but not in the latter.

The author further observes, that when any substance containing hydrogen, such as wood, oil, &c. is burnt in oxygen gas, a small quantity of the hydrogen escapes combustion, however great the excess of the oxygen is, and even cannot be ignited in this excess of oxygen by the electric spark. The only way of detecting and estimating this hydrogen, is to add 100 additional measures of hydrogen to 200 of the impure oxygen to be examined, which are then in the proportions capable of detonation; and then to observe whether the condensation is greater than would be produced by pure hydrogen and oxygen, allowing 200 measures of the former to condense 100 of the latter. M. Saussure asserts that every kind of hydrogen, even that obtained by the electrization of pure water, contains a small portion of carbon, so as to furnish a sensible quantity of carbonic acid when burnt with the purest oxygen which has pre-

viously been agitated with potash. This carbonic acid he finds to be about 3 measures from 1000 of hydrogen and 1000. of oxygen, but it is only made sensible when an excess of oxygen is employed; for when, on the contrary, an excess of hydrogen is used, scarcely any indications of carbonic acid are given, but the author asserts that then the unconsumed hydrogen is to a certain degree oxy-carburetted.

When a mixture of oxygen and azote is exposed to the electric spark with hydrogen in Volta's eudiometer, a sensible quantity of the azote is condensed, which in a single detonation may amount to 2 per cent. of the azote present. When much oxygen remains after the combustion, the condensed azote furnishes nitric or nitrous acid; but when the hydrogen is in excess, the azote produces nitrat of ammonia. This same ammoniacal salt is always generated by the slow combustion of hydrogen and of oxy-carburetted hydrogen in the open air.

The carbonaceous substances burnt in these experiments were plumbago, anthracite, charcoal arising from the decomposition of oil of rosemary, box-wood charcoal, and the charcoal which remains after passing the vapour of sulphur through it in the preparation of carburetted sulphur. The mode of performing these experiments was considerably complicated, as may be inferred from the preliminary eudiometrical remarks.

We shall select the experiment on the combustion of plumbago: 0.588 grammes of Cornish plumbago dried at a red-heat was burned in the receiver full of oxygen gas for an hour by the sun's rays collected through a lens. There remained 0.33 grammes of red oxyd of iron, the oxygen of which was .0099, and the iron therefore was .0231, and hence the carbon consumed was $0.588 - 0.0231 = 0.5649$. The gas before combustion, reduced to the standard pressure and temperature, was 1758.8 cubic centimetres, and after combustion 1750.4, giving a diminution of 8.4. The vessel of muriat of lime enclosed in the receiver had increased in weight 5 centigrammes, one of which is to be reckoned as the moisture absorbed from the air during the short time of its introduction into the vessel before the experiment, so that the moisture absorbed from the gas alone was 4 centigrammes, which is within $\frac{1}{50}$ of the quantity of moisture contained in the undried oxygen at the temperature employed. Hence it appeared that no water was produced by the combustion of the plumbago.

The oxygen examined before combustion, by the test of hydrosulphuret of potash, she

10.25 measures in 200 of azotic impurity; 200. measures of the same oxygen were also detonated with 400. of hydrogen, and the whole was reduced to 33 measures, so that 567 measures had disappeared in the form of water. Of this, one third is the oxygen, amounting therefore to 189, and if to this be added the 10.25 of azote found by the hydrosulphuret, the whole 200 of the oxygen employed will be accounted for, except 0.75, which is too small to be noticed. Hence the gas before combustion, consisted of

1669.8 measures of oxygen
89. azote

1758.8

The gas after combustion amounted to 1750.1. measures, from 100 of which the caustic potash absorbed 63.42 of carbonic acid. Another portion of the same gas was detonated with a mixture of equal parts oxygen and hydrogen, and the residue with potash to absorb the carbonic acid always produced by the combustion of oxygen and hydrogen, arising (as the author asserts) from the carbonic impurity of the hydrogen. The diminution of volume and the carbonic acid produced were no more than would arise from the hydrogen added to effect the detonation, whence it is inferred that no hydrogen was elicited by the combustion of the plumbago. Another 100 parts of the gas remaining after the experiment, examined by hydrosulphuret of potash, shewed 87 of oxygen and 13 of azote; and another 100 parts of the same gas detonated with 200 of hydrogen were reduced to 40. shewing 86.66 per cent. of oxygen and 13.34 of azote. Hence the composition of the 1750.4 measures of gas remaining after the combustion of the plumbago, is the following:

Cubic centimetres.

1110.1 of carbonic acid gas
557.06 oxygen gas
83.24 azotic gas

1750.4

If the combustion of the carbonic acid is inferred from the quantity of oxygen gas required to produce it, it will be found that the volume of oxygen gas consumed by the combustion is, $1669.8 - 557.1 = 1112.7$ cubic centimetres, of which 7.3 are employed to oxydate the iron, leaving 1110.1 as the oxygen entering into the carbonic acid produced. Hence converting the measures to their equivalent weights, and adding the weight of the plumbago consumed, the com-

position of 100. parts by weight of carbonic acid will be 72.64 oxygen and 27.36 carbon.

If the computation be made from the weight of the plumbago consumed, and that of the carbonic acid consumed, the proportions of 100. parts of this acid will be 72.61 oxygen, and 27.39 carbon.

The combustion of box-wood charcoal conducted in the same manner, gave 72.85 of oxygen to 27.15 of carbon.

The charcoal of essential oil shewed 72.88 oxygen to 27.12 carbon.

As no hydrogen appeared to be given out, either from the charcoal of essential oil, or from the plumbago, it would appear that these are the experiments on which the greatest confidence may be placed, and the mean of these gives for the composition of 100. parts by weight of dry carbonic acid, 27.29 parts of carbon and 72.71 of oxygen.

A second series of experiments on the combustion of diamond and other carbonaceous matter has been undertaken by M. Guyton Morveau.^d The apparatus employed by this eminent chemist nearly resembled that of Messrs. Allen and Pepys, and consisted of two gasometers connected by a tube, the center part of which was of platina and was passed through a furnace. The substance to be burnt was enclosed in the platina tube, and oxygen gas was passed over it repeatedly from one gasometer to the other as long as the experiment lasted.

M. Guyton made the very important addition of a tube filled with dry muriat of lime enclosed in each gasometer to absorb any moisture, and the gas immediately on entering and quitting the platina tube, was exposed to artificial cold to enable it more completely to part with any moisture which it might contain. As the oxygen was previously dried, any moisture condensed in the tubes of muriat of lime was inferred to arise from the generation of water by the hydrogen of the substance burned, with the oxygen employed. Hence this hydrogen was estimated at $\frac{1.4}{100} : \frac{2.8}{1000}$ of the increase of weight acquired by the muriat of lime.

M. Guyton estimates the weights of all the gasses concerned to be as follows: the pressure being 0.758 metre, (29.8432 Eng. inches) and 12.5° cent. Ther. (54.5° Fahr.)

One litre of	Grammes.
Dry Oxygen gas	1.3435
— Common air	1.2247
— Azotic gas	1.1987
— Hydrogen gas	0.1032
— Carbonic acid gas	1.8372

^d An. Chim. tom. 84.

The composition of water is assumed to be (by weight.)

Oxygen	—	85662
Hydrogen	—	14338

100000

And of carbonic acid (by weight)

Oxygen	—	72624
Carbon	—	27376

100000

And of carbonat of barytes (by weight)

Carbonic acid	—	221.
Barytes	—	779.

1000.

The weight of the litre of dry carbonic acid reduced to English measure is as follows: 1 litre = 61.028 Eng. cub. inches, and 61.028 cub. in. at 29.8432 inch pressure = 60.709 cub. in. at 30 inches. And 60.709 at 54.5° therm. Fahr. = 61.404 cub. in. at 60° Fahr. allowing the expansion of $\frac{1}{480}$ for every degree of this thermometer. And 1.8372 grammes (the weight of a litre of dry carbonic acid) equals 28.3737 troy grains, and hence 100. cub. inches of dry carbonic acid at 30. inches bar. and 60° therm. weigh 46.20 Troy grains.

M. Guyton's experiments gave the following results. The combustion of 1.435 grammes of oak charcoal, previously heated by itself, caused the deposition of only 0.065 grammes of water, the hydrogen of which is 0.00932, which therefore does not exceed $\frac{1}{1000}$ of the charcoal burnt.

Cumberland plumbago in the same way was inferred to contain $\frac{1}{1000}$ of hydrogen.

Piedmont plumbago contained $\frac{1}{1000}$ of hydrogen. Diamond in one experiment shewed $\frac{2.97}{1000}$ of hydrogen; but another more accurate trial gave at the utmost not more than $\frac{1.7}{1000}$. and part of this small quantity might possibly be furnished by the water of crystallization which may be supposed to exist in this crystallized form of carbon.

From the general results of these experiments it does not appear that any decided chemical difference can be detected between diamond, pure plumbago, and charcoal.

CARBURETTED HYDROGEN. OLEFIANT GAS. CARBONIC OXYD. OXYCARBURETTED HYDROGEN. COAL GAS.

^a Mem. d'Arcueil, tom. 2.

The constitution of the compound inflammable gasses, obtained by the distillation of vegetable matter or of moist charcoal, is a subject of extreme difficulty, which has given rise to various opinions among chemists. The only substances that constantly compose these gasses are carbon, hydrogen, and oxygen, but the respective proportions of these vary greatly, and the only mode of certain analysis is by compleat combustion with oxygen, thus reducing the whole to carbonic acid and water. It is obvious therefore that this mode of examination will not resolve the question of the intermediate composition of these gasses, but will only give their ultimate analysis, so that a gas may consist, for example, either of a triple compound of oxygen, carbon and hydrogen, (oxycarburetted hydrogen) or may be a compound of carburetted hydrogen and carbonic acid, and in each case will afford precisely the same results by ultimate analysis into carbonic acid and water.

Berthollet has asserted that all these gasses produced either by the distillation of moist charcoal or by the destruction of vegetable matter at a high heat contain oxygen, and are properly species of oxycarburetted hydrogen, the elements of which may combine in infinite proportions. He founds this opinion, partly on his own experiments on the products of moistened charcoal, and partly on those of Th. de Saussure on the gasses produced by passing the vapour of ether and alcohol through an ignited tube; all of which are found to contain a notable quantity of oxygen. On the other hand, it is maintained by Dalton, Thomson, Henry, and other eminent chemists, that there are two distinct species of carburetted hydrogen, namely, the pure *Carburetted Hydrogen*, a natural product of stagnant waters in the summer; and that singular gas obtained by the distillation of sulphuric acid and alcohol, called by the inventors *Olefiant Gas*, or, from its composition, it may be termed *Super-carburetted Hydrogen*. A mixture of these two species with pure hydrogen and with carbonic oxyd, and with empyreumatic oil, will (according to these chemists) account for all the known varieties of specific gravity and of oxygenation in all the other compound gasses. We shall merely give a short abstract of some of the most important experiments.

Those of Dr. Thomson are highly interesting.^b He considers the great variation in the specific gravity of the gasses obtained by dis-

^b Phil. Journ. vol. 88. p. 321.

tilling coal and other oily substances as chiefly owing to the oil held in solution by the gas. He therefore selected for analysis the gas that rises in considerable quantity from stagnant waters during the summer season, which had been before examined by Cruikshank and Dalton. This gas always contained 12.5 per cent. of common air, and from 5 to 7 of carbonic acid, which latter being removed, the specific gravity of the remaining gas was 0.611, equal to 0.554 after the removal of the common air, the specific gravity of the latter being 1.000. This gas burns with a large yellow flame, and detonates when mixed with not less than its own bulk of oxygen and ignited. On an average 100 measures of this gas ignited with 205. measures of pure oxygen form 104 of carbonic acid gas. But as carbonic acid contains only its own bulk of oxygen, the 104 parts only employed 104 of the 205 of oxygen consumed, and hence the 101 remaining measures went to the production of water and required 202 measures of hydrogen for that purpose. Reducing these to the proportions by weight (reckoning carbonic acid to contain 27.5 per cent. of carbon) the composition of the pure carburetted hydrogen of this gas from stagnant water would give nearly as follows:

Carbon . . .	72.
Hydrogen . . .	28.
	100.

In fact the sum of the constituent parts thus found would rather exceed the weight of the original gas, which at any rate would shew that no oxygen nor any other ponderable substance could be present. If this analysis is correct, and it agrees very nearly with that of Dalton, this gas (after extracting the common air and carbonic acid) is not an oxycarburetted hydrogen but a simple carburetted hydrogen, and is considered by Mr. Dalton as composed of one atom of carbon and two atoms of hydrogen.

Olefiant gas is the next definite compound examined by Dr. T. It was obtained in the usual manner by mixing one measure of alcohol with three of sulphuric acid, and boiling the mixture almost to dryness in a small retort, and collecting the gaseous product over water. This consisted of olefiant gas mixed with carbonic acid, which last increased in proportion as the process was continued.

This olefiant gas deprived of carbonic acid but retaining 16 per cent. of common air, was

found to have the specific gravity of 0.9786, hence, by calculation, pure olefiant gas would give 0.9745 sp. gr. (common air being 1.000.)

Olefiant gas when mixed with thrice its bulk of oxygen and ignited, detonates with extreme violence and produces twice its bulk of carbonic acid, according to Mr. Dalton, which very nearly coincides with Dr. Thomson's experiments. A hundred cubic inches of it (at 60° therm. and 30. bar.) weighed 29.72 grains. The weight of its constituent parts (considered merely as carbon and hydrogen) as found by analysis, somewhat exceeded the gas employed, a proof that it could contain no oxygen.

In average numbers it may be considered as containing

Carbon . . .	85.
Hydrogen . . .	15.
	100.

Mr. Dalton considers it as containing an atom of carbon and an atom of hydrogen.

Olefiant gas derives its name from its forming a singular oily-looking liquid when mixed with oxymuriatic gas, as already described (Chem. Dict. vol. I. p. 257.) Dr. Thomson has further examined this curious substance. A large bottle was filled with olefiant gas and a current of oxymuriatic gas being passed into it, the oily substance soon collected at the bottom. Its colour was greenish-white. When dropped into water it fell to the bottom, but gradually dissolved in it by agitation, and gave the water a sweet and cooling taste, and a slight aromatic odour. It dissolved completely in alcohol and sulphuric ether, but not in oil of turpentine. When left in an open vessel it evaporated, leaving only a greenish trace. It appears therefore to be totally distinct from the oils.

Olefiant gas is also obtained as a small part of the compound inflammable gas from coal, from caoutchouc, from mineral tar and other combustible bodies. It is separable from common carburetted hydrogen by oxymuriatic gas as will be further noticed.

Olefiant gas has been more lately analyzed by Th. de Saussure.* To diminish the extreme violence of the detonation where this gas is ignited with about thrice its volume of oxygen (the quantity that saturates it) the author employed a much larger proportion of oxygen. The general results were the following: 100. parts, in volume, of olefiant gas, were detonated

* An. Chim. tom. 78.

with 500. of oxygen deprived of carbonic acid, but containing 23.5 of azote. The mixed gasses were reduced by the detonation to 409.5 parts, from which potash extracted 201. of carbonic acid, and hydrosulphuret of potash 184.5 of oxygen, leaving 24 parts of azote. Hardly $\frac{1}{100}$ of the olefiant gas escaped combustion, for, on adding a known quantity of hydrogen to part of the entire residue of the detonation and again exploding it, the diminution was scarcely more than would have been produced by adding the hydrogen alone, and sufficient oxygen.

By subtracting the oxygen of the carbonic acid produced in this experiment from the entire quantity consumed, and finding the weight of hydrogen required to convert this remaining oxygen into water, the author finds in 100 parts, by weight, of olefiant gas, 84.78 of carbon and 13.55 of hydrogen, reckoning 27.2 of carbon in 100. of carbonic acid. This computation leaves only 1.67 of the 100. parts of olefiant gas unaccounted for, which is quite within the limits of unavoidable errors; for, in another experiment conducted in the same way, the sum of the carbon and hydrogen a little exceeded the olefiant gas employed. Hence M. de Saussure concludes that pure olefiant gas, in the preparation of which the distillation has not been carried too far, contains no oxygen, but is composed simply of about 86. of carbon and 14. of hydrogen, proportions which agree very closely with those of Dalton and Thomson. The specific gravity of this gas was about .985, common air being 1.000. If 15 parts by weight of hydrogen condense to half their volume by dissolving 85 parts of carbon, the resulting olefiant gas would by calculation, be found to have nearly the above specific gravity.

It has been mentioned in the original article (Ch. Dict. vol. 1, p. 257) that when olefiant gas is exploded with little more than its own

bulk of oxygen, so much carbon is precipitated in substance as entirely to blacken the vessel. Dr. Thomson has repeated this experiment, employing rather less oxygen than olefiant gas. After the explosion, the bulk of the residue is much greater than that of the gasses before explosion, being increased in about the proportion of 16 to 10.; or in still greater proportion if the uncombined oxygen that remains in the residue be removed. This residuary gas is much lighter than olefiant gas, having the specific gravity of only 0.48, and is considered by Dr. Thomson as a proper *oxycarburetted hydrogen*, or triple compound of oxygen, carbon, and hydrogen, and the proportions would nearly indicate the combination of an atom of each of these elements.

A great number of interesting experiments have been made at different times by Dr. Henry, on all the above described inflammable gasses, more particularly with a view to direct the economical use of the gas procured from the distillation of coal, which has now become an object of considerable national importance. Dr. Henry's first series of experiments, though confessedly imperfect, requires a short notice in this place.^d Dr. Henry constructed an Argand lamp, to be supplied with gas instead of oil, and found that both pure hydrogen and carburetted hydrogen, from moist charcoal, and carbonic oxyd, gave so trifling a light as to be entirely unfit for the purposes of illumination; while on the other hand the gas distilled from coal, gave a light little inferior to that from good spermaceti oil. Neither is this difference materially owing to any oily matter mechanically suspended in the coal gas, since it retains its power of burning with a bright dense light after being long kept over water, though somewhat impaired in intensity. The following gasses were then burnt with oxygen in close vessels, and the comparative quantities required for saturation were noted.

Kind of Gas.	Oxygen required to saturate 100 measures.	Carbonic Acid produced.
Pure Hydrogen	50	0.
Gas from moist Charcoal	60	35.
Wood	54	33.
dried Peat	68	43.
Cannel Coal	170	100.
Lamp Oil	190	124.
Wax	220	137.
Pure Olefiant Gas	284	179.

Phil. Journ. vol. xi. p. 65.

As there is much variation in the quality of most of these gasses, according to the circumstances in which they are procured, the above numbers are not to be considered as universally applicable, but they shew in a very satisfactory manner the comparative combustibility of this substance, as measured by the quantity of oxygen required for its consumption, and thus will account for the much greater intensity of light given by the latter over the former gasses. Above all others, the olefiant gas is as much distinguished by the splendour and beauty of its light as it is by the very superior quantity of oxygen which it requires for its combustion.

The specific gravity also of the gas is in some degree a test of the quantity of combustible matter which it contains, being in greater quantity as the gas is heavier, though this does not apply to carbonic oxyd but only to carburetted hydrogen.

In a later paper, Dr. Henry describes an apparatus of his own construction, for the better analysis of these gasses, which enables him to employ much larger quantities, and to consume them by slow continued combustion, which he considers as a much more accurate mode of analysis than by sudden ignition with oxygen in Volta's eudiometer.* But most of the gasses obtained by distillation of any combustible, and especially that from coal, which is the most important in the present view of the subject, are mixtures of several gasses, and cannot be properly analyzed by mere combustion with an excess of oxygen. Coal gas when first obtained consists of, carbonic acid, sulphuretted hydrogen, olefiant gas, and the remainder, which is by far the greater portion, is either a gas *sui generis*, an *Oxycarburetted Hydrogen*, or else a mixture of carburetted hydrogen and carbonic oxyd. It is therefore an important problem in analytical chemistry to be able to estimate these separately. Dr. Henry gives the following way, as at least affording an approach to accuracy in obtaining this object.

Sulphuretted hydrogen is absorbed by liquid potash, and by oxymuriatic gas.

Carbonic acid is absorbed by liquid potash, but is not altered by oxymuriatic gas.

Olefiant gas is immediately decomposed or absorbed by oxymuriatic gas, and is speedily absorbed by water, but is not acted on by liquid potash.

Carburetted hydrogen is not altered by oxymuriatic gas, except after some hours' contact, and it is not sensibly changed by water.

Therefore to analyze a coal gas (for example) first add two measures of the recent coal gas to one measure of oxymuriatic gas, and after a minute or two observe the diminution. Then wash an equal quantity of the coal gas with liquid potash to extract the sulphuretted hydrogen, and submit the residue to oxymuriatic gas as before. The second diminution by oxymuriatic gas, divided by 2.2 gives the proportion of olefiant gas. Deduct this absorption from the first, and divide the remainder by 1.8 for the quantity of sulphuretted hydrogen. Lastly, to find the quantity of carbonic acid, subtract from the entire diminution by potash the amount of the sulphuretted hydrogen.

By these operations the amount of the carbonic acid, sulphuretted hydrogen, and olefiant gas will be found, and when these are separated, there will remain only the oxycarburetted hydrogen, or mixture of carbonic oxyd and carburetted hydrogen (whichever it may be) which can only be analyzed by complete combustion with oxygen to determine separately the oxygen, carbon, and hydrogen, but which will not show the mode of constitution of the gas, but only the actual constituent parts.

The following general remarks on these gasses may be added. The olefiant gas is a very sparing product of the distillation of pit-coal. It is found only in the first portions, and does not compose more than 5 per cent. of these. It is absorbed in no great length of time by being in contact with water, and hence much washing of the gas or keeping it long over water is detrimental to its quality, since the olefiant gas is eminently combustible, and gives more light than any known species of inflammable gas containing either carbon or hydrogen. The gas from mineral tar or from caoutchouc, contains about one-tenth of olefiant gas.

Sulphuretted hydrogen is most abundantly produced from coal in the earlier stage of distillation, and then constitutes from one to five per cent. It increases the light of the gas but is unpleasant and injurious, by the sulphurous acid gas which its combustion generates. Part of the sulphuretted hydrogen unites, in the act of formation, with the ammonia of the coal, forming sulphuret of ammonia, which may be detected in the condensed products. Carbonic acid gas also appears only in the first products, and only in small quantity, never amounting to 5 per cent. The entire gas from coal undergoes a gradual diminution of combustibility, and with it, of specific gravity, during the

* Phil. Trans. for 1808.

whole distillation. Some of the latter products are so light that they can hardly be explained without supposing an evolution of pure hydrogen along with the other gasses. A cubic foot of coal-gas of medium quality, viz. of .622 specific gravity, such as is first afforded by the distillation of Newcastle coal, is stated by Dr. Henry to weigh 333.5 grains. This will yield by combustion 817.3 grains of carbonic acid, of which the carbon (at 28.6 per cent.) will be 233.7 grains, leaving 99.8 grains for the hydrogen in the cubic foot of the same coal gas. This gas will therefore require 1128.5 grains of oxygen for its complete combustion, of which 573.6 grains will go to form the carbonic acid with the carbon, and the remaining 554.9 grains will form water with the hydrogen.

Application of Coal Gas for the purpose of giving Light. This important application of coal gas was first made in 1792, by Mr. Murdoch, then Engineer-agent at Redruth, in Cornwall, to Messrs. Boulton and Watts, of Birmingham, who carried on many experiments on the gasses distilled from different kinds of coal, peat, wood, and other substances, as a substitute for oil or tallow, in giving light.

In 1798 the coal gas was first actually employed by Mr. Murdoch, for the common purposes of illumination, at the manufactory of Messrs. Boulton & Watts, at Soho, and since that time its use has been extended to all the principal shops in this vast concern, to the exclusion of all other artificial light. Mr. Murdoch has given the following account of the gas-light apparatus employed in the extensive cotton mill of Messrs. Phillips & Lee, at Manchester, with all the adjacent store-rooms and counting-houses.* The total quantity of light used during the hours of burning, has been ascertained by a comparison of shadows, to be about equal to the light of 2500 mould candles, of six in the pound, each of the candles consuming at the rate of $\frac{4}{10}$ ths of an ounce of tallow per hour. The coal is distilled in large iron retorts, which during the winter season are kept constantly at work, except during the intervals of charging, and the gas as it rises from them is conveyed by iron pipes into large reservoirs or gazometers, where it is washed and purified, previous to its being conveyed through other pipes, called *mains* to the mill. These mains branch off into a variety of ramifications, forming a total length of several miles, and terminate by burners, where the gas is con-

sumed, each of which is furnished by a cock to regulate the admission of gas, or to shut it off totally when not wanted. The burners are of two kinds, one resembles the common Argand lamp, the other is a small curved tube with a conical end, having three perforations of about a thirtieth of an inch in diameter, forming, when lighted, three divergent jets of flame. When the whole of the burners are used, the light is about equal (as already mentioned) to that of 2500 candles, and they require an hourly supply of 1250 cubic feet of the coal gas. The coal employed is the best Wigan cannel coal, which gives a gas much superior in quantity and quality to that of any other kind of coal. To supply two hours consumption of gas (which is about the daily average taking the year through) 2500 cubic feet of gas are required, to produce which, seven hundred weight of cannel coal must be distilled daily, or about 110 tons yearly.

About one-third of the above quantity of good common coal is required for fuel to heat the retorts. The 110 tons of cannel produce about 70 tons of good coak. Each ton of cannel coal gives from 11 to 12 ale gallons of coal tar. Mr. Murdoch adds the estimates of the expence attending each mode of illumination, by which it appears that where only two hours of daily average lighting are required, the annual expence of the coal gas is about £600, and that of an equivalent number of candles, is about £2000. A greater proportional saving is of course made by working the coal gas apparatus to its full extent, which in the present instance might be about equal to three hours daily consumption with the same apparatus.

The coal gas gives a peculiar soft, clear, and steady light, and it has the additional advantage over candles in requiring no snuffing and trimming, and therefore in avoiding one source of danger from fire, to which cotton mills are peculiarly exposed.

A very accurate description of a gas-light apparatus on the large scale, is given by Mr. T. Clegg,† with an illustrative plate. Mr. Clegg has actually put it in practice in several instances, and has succeeded in rendering the combustion of these lights free from any offensive smell. Indeed this smell chiefly, if not entirely, arises from the escape of a portion of the gas unconsumed. He estimates the cost of a complete apparatus capable of supporting forty lamps for four hours, each lamp afford-

* Ph. Trans. for 1805. p. 124.

† Ph. Journ. vol. xxiii. page 86.

ing light equal to ten candles of eight in the pound, to be about £250. Each lamp consumes six cubic feet of gas per hour.

Mr. B. Cook of Birmingham, has given the results of his experience in the employment of coal-gas light.^s Among other advantages it is particularly convenient for that kind of soldering which is now performed with the oil-lamp, for the gas light gives a sharper flame, and is also ready at the instant, whilst with oil and cotton the workman is always forced to wait for his lamp being sufficiently kindled to do his work. Mr. Cook has also turned to great advantage the mineral tar which distills from the coal whilst the gas is preparing. Four pounds of the coarse tar are obtained, on the average, from every hundred weight of good coal; and this tar, when redistilled, will yield half its quantity of a volatile oil, fully equal to oil of turpentine for the purpose of japaning, and a residue will be left, nearly, if not quite, equal for the same uses to the best asphaltum. These varnishes obtained the honorary medal from the Society of Arts. Mr. Cook adds a minute account of the whole apparatus and processes for obtaining the gas and the spirit.^h

CARBURETTED SULPHUR. See **SULPHUR** *Alcohol of*.

CHABASIE. Cubic Zeolite, J. Wurfel Zeolith, W.

Its colour is whitish, and sometimes pale-red superficially. It occurs crystallized in rhomboids, the obtuse angle of which is $93\frac{1}{2}^{\circ}$, either perfect or with the obtuse lateral edges truncated and combined with other modifications. It presents natural joints in three directions. It varies from transparent to translucent. Scratches glass with difficulty. Sp. gr. 2.7. Is readily fusible into a spongy white enamel; and is composed, according to Vauquelin, of

43.33	Silex
22.66	Alumine
3.34	Lime
9.34	Soda mixed with potash
21.	Water
99.67	
0.33	loss

Chabasie occurs forming glands in trap rocks in the island of Ferroe, and lining the inside of agate geodes at Oberstein in the Palatinate.

CHLORINE. See **MURIATIC ACID**.

CHLORINE AND AZOTE. (*New deto-*

nating compound of.) See **AZOTIZED OXY-MURIATIC ACID**.

CHROME.

In consequence of the abundant discovery of chromate of iron in France, M. Vauquelin has been induced to repeat his experiments on this substance, of which the following is a summary.^a

Decomposition of the native Chromate of Iron.

This is best effected by levigating the ore, mixing it accurately with half its weight of nitre, and keeping it in a state of ignition for half an hour or more. The mass does not enter into fusion, yet the nitre is entirely decomposed and the alkaline base is generally completely saturated by the chromic acid. The mass is to be pulverized and very accurately lixiviated in water till every thing soluble is taken up. The residue is then to be digested with warm and dilute muriatic acid, which takes up the iron, the magnesia, the alumine and the silex. When the action of the acid has ceased, it is to be poured off whilst warm lest it should become gelatinous and thus impede its separation from the insoluble part. The residue not taken up by the acid, after being well washed is again to be mixed with nitre in the proportion of one-fourth of its weight and to be treated as at first. When thus by the alternate application of nitre and muriatic acid the entire decomposition of the chromate of iron has been effected, the alkaline solutions are to be added together, and after being saturated with nitric acid are to be crystallized. By this means a little earth and chromate of iron are got rid of; and thus, if all the processes have been performed accurately and if the nitre employed has been perfectly pure, there will be obtained pure chromate of potash.

Oxide of Chrome.

To a solution of chromate of potash add subnitrate of mercury, as nearly neutral as possible, as long as any precipitate takes place; this precipitate is chromate of mercury of an orange colour, verging more or less to yellow or red according to circumstances, and is to be repeatedly and very accurately washed in water in order to separate the whole of the nitre; being then strongly heated in a well luted earthenware retort till no more oxygen or mercury comes over, there will be obtained pure oxide of chrome the usual colour of which is green, but if the heat has been intense and long continued, it will be more or less of a brownish yellow.

^s Ph. Journ. vol. xxi. p. 293.

^h Ibid. vol. xxxi. p. 382.

^a Ann. de Chim. lxx. p. 70.

If the mercurial solution employed in the foregoing process is at the minimum of oxydation and as nearly neutral as possible, the only substances remaining in solution in the mother liquor are nitre and nitrate of mercury, when an excess of this latter has been made use of. Generally however the mercurial solution contains a considerable excess of acid as well as a mixture of nitrate at the maximum of oxydation; and in this case the residual liquor exhibits an amethyst colour, and affords with alkalies a pale green precipitate, which after being heated is converted into oxide of chrome.

If this precipitate instead of being heated is digested with cold caustic alkali, it communicates to the liquor a bright green colour, and there remains undissolved a red powder exhibiting all the properties of the per-oxide of mercury. The alkaline solution itself when filtered and boiled, deposits a large quantity of flocculent green oxide of chrome, and acquires a golden yellow colour, being in fact an alkaline chromate of potash.

Chromate of Barytes.

This salt is most conveniently prepared by adding to a solution of pure and neutral chromate of potash nitrate of barytes as long as any precipitation takes place. The precipitate is insoluble even in a large quantity of warm water, and should therefore be washed repeatedly in order to free it entirely from any mixture of nitre.

Five grammes of this salt being dissolved in warm and dilute nitric acid, afforded on the addition of sulphuric acid in excess 4.4 grammes of sulphate of barytes: hence (estimating sulphate of barytes to contain 68 per cent. of base) chromate of barytes is composed of

62.6 Barytes

37.4 Chromic acid

100.0

Further, since 5 grammes of chromate of barytes contain 1.87 grammes of concrete acid, and since this latter by a strong calcination is reduced to 1.56 grammes of green oxide, it follows that 100 parts of green oxide require 16.6 of oxygen for their conversion into chromic acid.

Chromic Acid and Oxide.

The most convenient way of preparing chromic acid is to dissolve chromate of barytes in dilute nitric acid and then to precipitate the barytes by the addition of sulphuric acid, taking particular care not to leave this latter in excess.

The liquor is then to be filtered, and contains only nitric and chromic acids: in order to get rid of the first the whole must be evaporated to dryness repeatedly, with the precaution of not pushing the heat too much towards the latter end of each evaporation. When the chromic acid is much concentrated, it appears in the form of mammillated masses with intermixed crystalline grains: by exposure to the air it deliquesces. The colour of chromic acid is deep red, to the taste it is very acid and at the same time acerb and metallic: it is soluble in alcohol, but the solution soon becomes green owing to the partial decomposition of the acid.

If to a solution of chromic acid there be added a considerable quantity of sulphurous acid, the colour of the mixture becomes a dirty brown, from which caustic alkali throws down a redish brown precipitate, soluble in acids. A still larger quantity of sulphurous acid changes the colour of chromic acid to a pale green; hence there appear to be two oxides of chrome, differing however but little in their respective proportions of oxygen.

The oxide of chrome procured by calcination of chromate of mercury, is very difficultly acted on by acids, but when recently precipitated it is soluble with ease, even in the weakest acids.

Muriate of chrome when evaporated to dryness, affords a rose coloured powder, which deliquesces in the air, and acquires a bright green colour. When calcined at a pretty considerable heat, it gives out an odour of oxymuriatic acid, increases in bulk, and is converted into micaceous scales of a brilliant yellow; by a further continuance of the heat, it passes into green oxide.

Caustic potash added in excess to any of the solutions of oxide of chrome in an acid, effects a solution of the oxide; the same takes place if recently precipitated oxide is digested in the same menstruum. The solution is of a deep green colour, but by ebullition the oxide is separated, and the liquor remains colourless.

Alkaline, earthy and metallic chromates.

There are two chromates of potash, the neutral and the acidulous. The former is of a lemon yellow colour, and crystallizes in minute prisms. The latter is of an orange red colour, and crystallizes in large prisms.

Chromic acid, when saturated by ammonia, and exposed to spontaneous evaporation, produces a salt of a bright yellow colour, which climbs up the side of the vessel; by boiling, it deposits a brown flocculent oxide, which acquires a green colour by calcination.

Chromate of lime is readily soluble in water, and affords by evaporation, silky scales, of a yellowish brown colour.

Chromate of magnesia is also readily soluble in water, and crystallizes in six-sided prisms, of a high topaz yellow.

Chromate of iron is formed by combining chromic acid, and the red oxide of the metal. But if a lower oxide is employed, (as in mixing green sulphate of iron and chromate of potash) a fawn coloured precipitate is obtained, which, when treated with caustic alkali, gives no trace of chromic acid: it is readily soluble in muriatic acid, and is precipitated without alteration from its solution by an alkali. Nitric acid effects a partial solution of it, and becomes of a green colour. Hence this compound is not chromate of iron, but a combination of chromic oxide and red oxide of iron, being perfectly analogous to the so called native chromate of iron.

Chromate of lead acquires different tinges of colour, according to the mode in which it is prepared; if the chromate of potash is perfectly neutral, the precipitate is of an orange yellow; if with an excess of acid, it is a full lemon colour; if on the other hand the alkali is in excess, the precipitate is full orange or scarlet. The acidulous chromate with nitrate of lead furnishes the most permanent colour.

Chromate of copper is most readily prepared by adding neutral chromate of potash to sulphate of copper; a yellowish brown precipitate falls down, which when well washed and dried, acquires a bistre colour.

Chromate of silver is best prepared by decomposing nitrate of silver by neutral chromate of potash; if the solutions before mixture are hot, the result is a brownish red precipitate, but a purple red precipitate if they are cold. If acidulous chromate of potash is employed, the precipitation takes place more slowly, is less abundant, and assumes the form of minute semitransparent crystalline grains of a carmine red. All the varieties of this salt become brown by exposure to the air. It is soluble in nitric acid, and decomposable with abstraction of the oxyd of silver by muriatic acid.

Oxide of chrome supports better than any other colorific substance, the intense heat required for baking the hard porcelain, and gives a perfect emerald green of great beauty and value.

CINNAMON STONE. Kaneelstein, W.

Its colour is yellowish brown, passing into orange yellow and hyacinth red. It occurs in rolled and splintery fragments. Its internal

lustre is shining between vitreous and resinous; its fracture is imperfectly and small conchoidal, with joints not very visible parallel to the sides of a rhomboidal prism, the obtuse angle of which is about 100° . It is more or less transparent, scratches quartz, though with some difficulty, sp. gr. 3. 6.

It is fusible before the blowpipe into a brownish black enamel. It has been analyzed by Klaproth, with the following result.

38.8	Silex
21.2	Alumine
31.25	Lime
6.5	Oxyd of Iron
97.75	
2.25	Loss

This mineral has hitherto only been found among sand, near Columbo, in the island of Ceylon. It was at first supposed to be a variety of zircon; but this, its chemical analysis amply disproves. By M. Mohs, it is regarded as possessing a marked analogy with garnet.

COAL GASS. See CARBURETTED HYDROGEN.

COBALT.

§ 1. Ores of

Native sulphuret of cobalt.^a

The colour of this mineral is pale steel grey. It occurs massive and botryoidal, in the latter case often presenting superficially the rudiments of crystals. Its fracture is uneven, passing into granular, and presents a metallic lustre.

On exposure to the blowpipe, it exhales a sulphureous odour unmixed with that of arsenic, it acquires a deep grey colour, and fuses into a brilliant fragil globule. If previously calcined and then mixed with borax, it affords a deep blue glass, and a white regulus, attractable by the magnet.

It has been analyzed by Hissinger, and appears to consist of

43.2	Cobalt
14.4	Copper
3.53	Iron
38.5	Sulphur
0.33	Earthy matter
99.96	

It is a rare mineral, having been hitherto found only near Riddarhyttan, in Sweden, mixed with iron and copper pyrites.

§ 2. Chemical properties of Cobalt.

Several useful observations on the salts and

^a An. de Chim. lxxxiii. p. 329.

oxyds of cobalt have been made by Proust,^b some of which we shall briefly notice.

Oxyds of Cobalt. The author reckons two oxyds, the grey and the black, the former of which is the *Suboxyd*, and the latter the *Peroxyd*.

The carbonat of cobalt is made by saturating the sulphat of this metal by carbonated potash. Of this carbonat, 100 parts heated gradually in a retort, filled as full as possible, till all the water and carbonic acid are expelled, give 60 to 62 of the grey suboxyd. This dissolves in nitric acid without giving out nitrous gas. When heated in contact with air, it absorbs oxygen, and passes more or less completely to the state of black oxyd. When the two oxyds are mixed, a weak acid will dissolve out only the grey oxyd, and leave the other. Pure ammonia does the same.

When a solid crystal of sulphat or nitrat of cobalt is thrown into a phial containing a weak solution of liquid potash, a violet blue precipitate is formed, which is the *Hydrat of Cobalt*, or more properly the *Hydrated Suboxyd*. When this is heated it loses about 20 per cent. of its weight, and becomes very pure suboxyd.

The hydrat is very soluble in acids without effervescence. When long kept under water it gradually absorbs oxygen, and becomes black oxyd. 100 parts of pure suboxyd reduced carefully in a close crucible, left $83\frac{1}{2}$ of metal. Hence the author infers, that 100 parts of cobalt absorb 19 of oxygen to become grey oxyd.

The peroxyd is formed by distilling a nitrous solution of cobalt to dryness. Much nitrous gas escapes, and a black oxyd gradually separates. This peroxyd is insoluble without decomposition, in most acids; for when it does dissolve in them, it parts with oxygen in one form or other. It is also insoluble in ammonia. The cobaltic colouring matter of the beautiful blue glasses is the grey, and not the black oxyd. On the other hand, the carbonat and hydrat of cobalt become black oxyd by the contact of oxymuriatic acid. The nitrous and sulphurous acids dissolve the black oxyd without evolving oxygen, but the resulting salts are the nitrat and sulphat of cobalt.

The author estimates 100 of pure metal to absorb 25 or 26 of oxygen in becoming black oxyd.

Muriat of Cobalt is formed by dissolving grey oxyd in muriatic acid. The crystals of this salt are blue when quite *anhydrous*, but

become red in absorbing moisture. The green colour usually shewn by this solution, when used as a sympathetic ink, arises from the presence of a little nickel. When the black oxyd is heated with muriatic acid, oxymuriatic gas is given off, and the solution becomes the muriated suboxyd. This suboxyd also appears to be the basis of all the other salts of cobalt.

COCOLITE. See AUGITE.

COLD. (Artificial.)

A new and very curious application of the principle of producing cold by evaporation has been discovered by Professor Leslie. It consists in placing under the receiver of an air-pump two vessels, one containing a considerable quantity of concentrated sulphuric acid, or of muriat of lime, or of any other substance which absorbs moisture from the air, and the other vessel holding a small portion of water. As soon as the receiver is exhausted, the water begins to boil, though at a common temperature, and when a pretty good vacuum is made, the pumping may be stopped, and after a while the water becomes entirely frozen. For this experiment to succeed, the surface of the substance that absorbs the aqueous vapour, should be considerable, and concentrated sulphuric acid is preferred by Mr. Leslie to any other absorbent of moisture. The water to be frozen must be in small quantity, and contained in a thin metallic dish.

The experiment may be easily performed in the small way in a common air-pump, in the following manner: put into a wide glass tumbler six or eight ounces of good sulphuric acid, set this on the pump-plate, lay a little support of wire over the top of the tumbler, and set upon it a thin metallic vessel, holding two or three teaspoonfuls of water; cover the whole with the receiver, and work the pump till a considerable vacuum is made, and the gage is stationary, then let the whole remain for many minutes, and the water will gradually congeal till it is perfectly solid. If this is allowed to remain undisturbed, the vacuum being kept up by an occasional stroke of the pump, the ice gradually becomes rounded at the edges, porous, and insensibly shrinks in every dimension till it totally disappears, leaving only a little trace of whatever saline or earthy impurity the water may contain. Three or four hours will elapse, even in the heat of summer, before the ice of one or two drams of water thus frozen will be totally dissipated, and not the least appearance of melting is observed the whole time.

In this most striking experiment, the first

^b Ann. Chim. tom. 60.

effect of the exhaustion of the air is to cause the evaporation of a portion of the water, which is instantly absorbed by the sulphuric acid. This produces a fresh vacuum, which is again filled by fresh aqueous vapour, and this is again condensed by the acid; so that this alternate formation of vapour from the water, and absorption of it by the acid, continues as long as any portion of water remains either in the liquid or solid state, provided the acid is not too much diluted to retain its absorbing power.

The temperature of the acid rather encreases during this process, both from the condensation of vapour, and from the heat generated by the addition of water to the sulphuric acid. On this account it is of advantage to remove the water to be frozen as far distant as possible from the sulphuric acid. This acid absorbs moisture rapidly till it has gained about its own bulk of water.

Dr. Wollaston has contrived a very simple and striking application of this experiment. The instrument is the same as the common toy, called the pulse-glass, and consists of a glass tube with a bore of about $\frac{1}{8}$ of an inch in diameter, terminated at each end by a hollow ball, about an inch in diameter, and bent in a right angle at the distance of half an inch from each ball.^a The length of the tube intervening between each ball is immaterial to the experiment, and may be very considerable. One of these balls should be half filled with water, and the remaining cavity should be as perfect a vacuum as possible. The instrument being thus prepared, let the empty bulb be immersed in a mixture of salt and snow, and the water in the other ball (though the intervening length of tube be two or three feet) will be frozen solid in a very few minutes. The reason of this is, that the vapour of water contained in the empty ball is first totally condensed by the effect of the freezing mixture, and the vacuum thus produced gives opportunity for a fresh quantity of water to be evaporated from the half-filled ball with proportional diminution of its temperature, which in its turn is condensed, till sufficient vapour has been produced to bring the water that furnishes it, below the freezing point and to solidify it. The freezing mixture therefore in this instance has a similar effect with the sulphuric acid in Mr. Leslie's experiment.

Dr. Wollaston has given to this instrument the name of *Cryophorus*, or *Frost-bearer*.

^a Phil. Trans. for 1813.

COLUMBIUM.

In a paper by Dr. Wollaston,^b in the philosophical transactions, the identity of columbium and tantalum is very satisfactorily pointed out. In external appearance, columbite and tantalite bear a very close analogy to each other, except that the sp. gr. of the former is 5.91, while that of the latter is 7.95.

Five grains of columbite being fused for a few minutes with 25 grains of carbonated potash and 10 grains of borax, produced a deep green saline mass, which by the action of dilute muriatic acid was dissolved, with the exception of a portion of white oxyd, which after ignition weighed 4 grs. The muriatic solution being neutralized with carbonate of ammonia, afforded with succinate of ammonia a precipitate, from which by ignition were obtained $\frac{1}{4}$ of a grain of oxyd of iron. Lastly, prussiate of potash threw down prussiate of manganese, yielding by calcination $\frac{1}{4}$ of a grain of oxyd.

An equal weight of tantalite afforded by similar treatment

$4\frac{1}{4}$	grains of white oxyd
$\frac{1}{2}$	oxyd of iron
$\frac{1}{10}$	oxyd of manganese
4.95	

Both the white oxyds are nearly insoluble in any of the three mineral acids. In potash, either caustic or carbonated, they are readily soluble, one part of oxyd requiring about eight parts of the latter salt. The alkaline solution may be decomposed by means of any acid, and the recent precipitate, though not soluble in the mineral acids, is compleatly taken up by oxalic, tartaric, or citric acids.

Neither infusion of galls, prussiate of potash, or hydrosulphuret of potash occasion any change in the alkaline solution, but if this latter be saturated by an acid, the addition of tincture of galls occasions an orange precipitate: this precipitate is again soluble in either of the three vegetable acids already mentioned, as well as in pure ammonia, though the mild volatile alkali appears to have no such effect.

COPPER.

§ 1. Ores of

Emerald copper ore. Kupperschmaragd, W. Cuivre Dioptase, H.

Its colour is emerald green. It occurs crystallized in prismatic rhomboidal dodecahedrons, which exhibit a triple cleavage parallel to the

^b Phil. Trans. 1809. p. 246.

sides of an obtuse rhomboid, the alternate angles of which are $123^{\circ}.58'$ and $56^{\circ}.2'$. The lateral planes of the crystals are smooth, and both externally and internally are shining with a vitreous lustre. It is more or less translucent, and scratches glass with difficulty. Sp. gr. 3.3.

Before the blowpipe it becomes of a chesnut brown, and communicates to the flame a yellowish green colour, but does not melt; with borax it affords a globule of copper.

From an examination by Vauquelin of a small portion, scarcely equal to 4 grains, it appears to consist of

Silex	28.57
Oxyd of Copper . .	28.57
Carbonate of Lime .	42.85
	99.99

It occurs in Siberia, accompanied by malachite.

Some additional facts and experiments on the sulphuret and oxyds of copper will be found in the article *Affinity* of this appendix.

CRYOPHORUS. See COLD (Artificial).

D

DATHOLITE.

The only crystalline form of this mineral as yet known is a strait ten-sided prism, of which two opposite solid angles adjacent to each base are replaced by triangular facets. The colour is greyish-white and translucent: the hardness of the crystals exceeds that of fluor spar. The fragments when exposed to the flame of a candle become of an opaque white, and may then be easily rubbed down between the fingers. According to an analysis by Klaproth it is composed of

35.5 Lime
36.5 Silex
24. Boracic acid
4. Water

100.0

It occurs in the neighbourhood of Arendahl in Norway.

Var 1. Externally redish, internally grey; botryoidal; texture, concentric lamellar with very fine divergent fibres; fracture splintery.

Occurs also at Arendahl.

DIALLAGES.

Under this new species of M. Haüy are included the Schiller spar, regarded by Werner as crystallized serpentine, resplendent Hornblende, remarkable for its brilliant pseudo-metallic lustre, Bronzite usually ranked as a variety of the foregoing, and that variety of Actynolite to which Karsten has given the name of Smaragdite.

The crystallographical character of the species is, natural divisions parallel to the sides of a rhomboidal prism, the obtuse angles of which are a few degrees larger than a right angle, the prism hence resulting being still further di-

visible parallel to the two diagonals of the base.

The three varieties belonging to this species are,

1. Diallage verte, or Smaragdite, consisting according to Vauquelin of

50 Silex
21 Alumine
13 Lime
6 Magnesia

90

with a variable proportion of the oxyds of chrome and of iron.

2. Diallage Metalloide. Schiller spar, Bronzite, resplendent Hornblende: of which the Schiller spar has been analyzed by Drappier and the Bronzite by Klaproth, with the following results.

S.		B.
41.	—	60. Silex
3.	—	0. Alumine
1.	—	0. Lime
29.	—	27.5 Magnesia
14.	—	10.5 Oxyd of iron
10.	—	0.5 Water
98.		98.5

3. Diallage submetalloide.

Of a dark brown colour, with a slight semi-metallic tinge of violet.

DIAMOND. See CARBON.

DIASPORE.

The colour of this mineral is ash-grey with a moderately bright lustre between vitreous and resinous: it is composed of slightly curved lamellar concretions easily separable from each other. It exhibits natural joints parallel to the

faces of a rhomboidal prism, the angles of which are alternately 130° and 50° . Its hardness is somewhat superior to that of glass. Sp. gr. 3.4.

A small portion of this mineral when exposed for a few seconds to the flame of a candle is dispersed in fragments with a brisk decrepitation. If heated in a close crucible it assumes the appearance of boracic acid. It is composed, according to Vauquelin, of

80. Alumine
17. Water
3. Oxyd of iron

100.

Its gangue is a ferruginous clay.

Is not this mineral a mere variety of the WAVELLITE, first discovered by Dr. Wavel near Barnstaple in Devonshire, and since found in Brazil by Mr. Mawe?

DICHOITE. See IOLITE.

DIOPHASE. See COPPER.

DYEING. MORDANTS.

An enquiry of considerable extent and apparently conducted with much pains on the mode in which some of the most usual mordants unite with animal and vegetable fibre has been made by Messrs. Thenard and Roard, of which we shall give a short abstract.*

Of Alum Mordants.

When wool or other fibre is macerated with a solution of alum, either with or without other additions, this salt is commonly considered to be decomposed, the alumine alone remaining united with the animal or vegetable fibre, and thus serving as an intermede for the fixation of the colouring matter. The fact of this supposed decomposition was first examined.

Some silk, thoroughly cleansed and washed, was digested for six days at a common temperature with a solution of 100 grammes of alum in 4 litres of water. It was then taken out and washed in distilled water; the remaining liquor with the washings being then evaporated, yielded pure crystals of alum to the very last. The silk itself was then boiled with twelve successive portions of water, all of which were also evaporated, and gave nothing but pure alum. The entire quantity of alum thus recovered from the silk and from the remaining solution was within $\frac{1}{20}$ of the quantity of alum originally employed. The silk thus deprived of alum had no greater power of fixing dyes than if the alum-bath had never been used.

From this it is inferred that alum is not decomposed in the fibres of the silk.

Some wool was boiled repeatedly with weak muriatic acid to separate the carbonat of lime which naturally adheres to it. It was then boiled with many portions of fresh distilled water till no trace either of muriatic acid or of lime was left in the washings, (which was a very long and tedious operation) and the wool was left quite pure. Some of it was then boiled in a hot solution of a given quantity of alum, and thus prepared it took colouring matter with great ease. But after being repeatedly boiled in water, all the alum was washed out and most of this salt was recovered in the same state in which it was at first employed, though some of it remained mixed with an animal matter extracted from the wool, and could hardly be made to crystallize. The experiment was therefore repeated with the difference of using a cold alum-bath in the first instance, and then, by successive washing, the whole of the alum to $\frac{1}{400}$ th part was recovered in crystals unaltered. Alum therefore combines with pure wool without undergoing any change or decomposition.

Cotton and thread gave similar results, only that the subsequent extraction of the alum was much less difficult, as the union between alum and vegetable fibre is much weaker than with animal fibre.

The authors then examined the operation of the alum-bath on wool in its common state and not previously purified of the carbonat of lime which adheres to it. In all the common processes of aluming wool the alum liquor in which it is steeped becomes very turbid, and on cooling lets fall an abundant white precipitate. This was found to consist of sulphat of lime, of neutral sulphat of alumine, and sometimes of a little alumine. The clear liquor above the precipitate, on the other hand, contained alum and acid sulphate of potash with a little animal matter. The wool itself when boiled with water gave up merely alum with a very trifling proportion of this white precipitate. As this precipitate never appears when the wool has been carefully purified from the carbonat of lime, the authors examined the operation of this earth upon alum alone. Alum long boiled with carbonat of lime is totally decomposed by a sufficient proportion of it, into a solution of acid sulphat of lime and a deposit of sulphat of lime with subsulphat of alumine and potash.

Other earthy or alkaline salts have a similar

operation upon alum in changing it to a very acid sulphat of potash or ammonia, and an insoluble sulphat of alumine with potash and the earthy or alkaline matter employed.

Acetite of alumine also unites with animal or vegetable fibre at first without being decomposed, but by exposure to the air some of the acetic acid flies off, in consequence of which a *sub-acetite* of alumine remains in the fibre, together with a little mere alumine.

Cream of Tartar on Wool.

Some wool, prepared in the way already described, was macerated in a bath of very pure cream of tartar and then washed repeatedly in boiling water. About three-fourths of the cream of tartar used were recovered unchanged, and with it was some neutral tartrate of potash. The washings of the wool were strongly acid, and yielded a very little cream of tartar and a very acid compound of tartareous acid and animal matter. From this and the former experiments may be inferred the effect of wool upon the common mixed mordant of cream of tartar and alum, (since Berthollet has shewn that these salts do not decompose each other) the wool absorbs the alum totally, and a little of the cream of tartar unchanged, but a much greater part enters the wool with great excess of tartareous acid, and of course the liquor in which the wool is macerated contains a portion of the tartar with deficiency of acid, or in other words, as neutral tartrate of potash.

This was further proved by direct experiment. Wool was macerated in a bath of $\frac{1}{4}$ of its weight of alum and $\frac{1}{16}$ of cream of tartar: the remaining liquor gave alum, cream of tartar and a mixture of tartrate of potash and animal matter; and the wool itself when long boiled in pure water gave out an atom of cream of tartar and a quantity of a compound of tartareous acid, alum and animal matter. Hence the practical advantage of a compound alum and tartar mordant in cochineal, kermes and madder colours, where the tint is to be enlivened by an excess of acid in the mordant; and on the other hand this compound mordant should be avoided and alum alone employed, with weld, logwood and Brazil-wood dyes, that are degraded by acids.

Some trial was made of simple acids instead of alum as mordants. Wool boiled with a small portion of sulphuric, nitric, muriatic and tartareous acids appeared to take cochineal and madder colours as easily, and to exhibit as great a body of colour as with the alum mordant.

But the supertartrate of alumine appeared to fix a brighter tone of colour than any other mordant. With regard to the quantity of mordant no advantage was gained by encreasing it beyond a quarter of the weight of the stuff, nor by prolonging its maceration in the mordant beyond two hours.

Scarlet Dye.

This dye is usually produced on wool by macerating it with certain proportions of cochineal, cream of tartar, and a highly oxydated and acid solution of tin, in two successive operations. The precise effect of these two mordants was examined in the following way. Some cream of tartar and nitro-muriat of tin were mixed together, and a precipitate separated, which when washed and separately examined shewed the presence of tartareous acid, of oxyd of tin, and of a large excess of muriatic acid. The mother liquor contained cream of tartar, tartrate of potash, and a very acid muriat of tin, together with much of the last mentioned precipitate, but held in solution by the excess of acid. Some very pure wool was first steeped in the usual compound mordant of tartar and solution of tin, and then boiled many times with fresh water, which finally extracted the whole of the mordant which it had imbibed, apparently not differing from the precipitate formed by mixing the materials of the mordant solely. The fine cochineal scarlet therefore is a compound of wool, colouring matter, acid of tartar, muriatic acid and peroxyd of tin. Nevertheless the mordant liquor in which the precipitate is formed is essential towards bringing out the colour, which is done (as the authors conjecture) by its great acidity.

The tartrate of tin (obtained by tartrate of potash or soda and muriated peroxyd of tin) dissolved in muriatic acid, answers as well as the common mordant of cream of tartar and solution of tin.

The scarlet dye is not quite firmly fixed into the wool by any of the processes, hence it may be gradually washed out by repeated maceration in warm water, till no other hue remains on the wool than a pale flesh-colour.

The researches of these chemists are evidently imperfect, but the main points which they mean to establish are, the combination of alum with animal fibre without any decomposition of the alum, and the change in the tartar solely, by which its acid is fixed on the cloth; and likewise the powerful effect of the colouring matter to fix the mordant on the ani-

mal fibre, which is no less powerful than the action of the mordant as an intermede for colouring matter.

Acctite of Alumine.

Some valuable remarks on this salt, which is so largely used by the calico-printers, will be found under the article ACETIC ACID in this Appendix.

E

ETHER. See ALCOHOL.

EUCHLORINE. See MURIATIC ACID.

F

FERMENTATION. See ALCOHOL.

FETTSSTEIN. Pierre grasse, H.

The colour of this mineral is a deep greenish-grey; it occurs crystallized and amorphous, and presents natural joints parallel to the faces of a strait rhomboidal prism and also parallel to the short diagonals of the bases. Its fracture is uneven, with a greasy lustre and slightly chatoyant. It scratches glass and gives sparks with steel. Sp. gr. 2.61.

It is easily fusible before the blowpipe into a white enamel, and is composed, according to Vauquelin of

44.	Silex
34.	Alumine
4.	Oxyd of iron
0.12	Lime
16.5	Soda and potash (the former
	being in the greatest
98.62	proportion.)

It has hitherto been found only in Norway.

FLUORIC ACID. FLUOR SPAR. A very valuable memoir on this acid has been published by Messrs. Gay Lussac and Thenard,^a who have discovered some very curious circumstances relative to this singular acid.

The reader will find it stated (*Chem. Dict. Art. Fluoric Acid*) that fluoric acid prepared from fluor spar, and distilled with sulphuric acid, always carries with it a portion of the silex of the glass when prepared in glass retorts, and therefore that the only way to avoid the presence of this earth, was to select a pure fluor spar and to employ leaden vessels. This way however has been thought to introduce a different impurity, namely, a portion of the lead of the vessel used, but the authors of the present memoir scarcely allow of this. Previous to the researches of these eminent chemists the fluoric acid had only been obtained in a dilute state, the distilled acid being received in water, but the present memoir makes us for the first

time acquainted with *pure concentrated liquid Fluoric acid*. It is prepared in the following way.

The apparatus consists of three leaden tubes, which must be made without any solder and ground to fit as well as possible: the tube A. (Plate, Fig. 5) contains the fluor spar and sulphuric acid: the bent tube B. conducts the distilled acid into the tube receiver C. set in a vessel of ice. Select some very pure fluor spar quite free from any crust of quartz which often covers this mineral, reduce it to fine powder and put it with about twice its weight of concentrated sulphuric acid into the tube A, which is set in a small furnace, and stir the materials well with an iron or copper rod. Lute all the joinings carefully with fat lute (for the lead can never be made to fit close enough by mere grinding) and then heat the tube very gradually, which must not be above two-thirds full. Soon a boiling will be heard, and the pure fluoric acid will pass through the conducting tube B. to the receiver C. where it will condense into the liquid acid. The operation is finished when on detaching a little the conducting tube from the receiver, the end of the former is no longer moist. Besides applying the heat gradually and very moderately, it is of use not to keep it up longer than necessary, as the sulphat of lime sticks very closely to the leaden tube and cannot be got off without difficulty. Instead of the above simple apparatus, some chemists use with equal success a leaden retort (made of two pieces fitting to each other for greater convenience) and the beak fitted to a leaden receiver.

Before we mention the chemical properties of this acid, we shall notice by way of precaution the excessive caustic property which it possesses in destroying all animal matter. The instant that a drop of the concentrated acid touches the skin it destroys the surface, a violent pain soon follows, the adjacent parts be-

^a Recherches, tom. 2.

come white and painful, and a deep boil or slough is produced in the flesh, forming a sore which takes several days or even weeks to heal, and even endangers the whole finger if the quantity of acid amounts to some drops.

A single instant of contact of the concentrated acid appears sufficient to produce the mischief, which will take place several hours after the time of contact; so that chemists who repeat these experiments should take particular care to avoid these accidents when replacing the lute, pouring out the acid, &c.

The concentrated Fluoric Acid thus obtained is a liquid at any temperature from -4° Fahr. to 60° . The heat at which it boils is not ascertained, but it is certainly easily evaporable, especially when in contact with air; for thus exposed, it soon wastes away at a very moderate heat. It is difficult to find proper vessels to keep this powerful substance. Glass vessels of course are improper, as the acid instantly corrodes them; and many of the metals are also acted on by it. Leaden vessels would answer very well if it were not for the difficulty of making any leaden stopper to fit properly without the assistance of lute, which itself is gradually altered by the acid vapour. The authors of this memoir prefer silver vessels.

As soon as the concentrated fluoric acid is exposed to the air it absorbs the atmospherical moisture, and in so doing emits abundance of strong suffocating vapours, which should be carefully avoided. When a few drops of the acid are added to water much heat is produced and a noise like that of quenching red-hot iron; in which respect it resembles and is even superior to, the strongest sulphuric acid.

The moment this fluoric acid touches glass it takes off its polish, the acid heats, boils, and totally disappears, resolving itself into silicated fluoric acid gas, exactly similar to that produced by distilling fluor-spar and sulphuric acid from glass vessels. This may be shewn in a striking manner by distilling the pure acid from a vessel as above described, but instead of using a leaden receiver causing the conducting leaden tube (previously dipped in melted wax to protect it from the action of mercury) to pass under a glass jar full of mercury and inverted over this fluid. As soon as a drop of the strong liquid acid touches the inner part of the glass receiver it attacks the glass, makes it opaque, and the acid is speedily converted into vapour along with the silix of the decomposed spot of glass, which is shewn by its displacing an equivalent volume of the mercury with which the tube

was filled. There remains on the glass a solid matter composed of acid fluat of silix with a little of the wax. Though this silicated gas is formed almost instantaneously, it appears to be as fully saturated with silix as that procured by the slow distillation of fluor-spar, glass, and sulphuric acid. Fluoric acid therefore when pure is in a liquid state, however concentrated, if the temperature does not exceed about 60° , but its union with silix enables it to assume the form of a permanently elastic gas at any temperature, which however is absorbed and decomposed by water, as will be presently mentioned.

When the pure fluoric acid is diluted with so little water as still to emit fumes in the air, its action on silix is still instantaneous, and it equally retains the property of resolving itself by this action into silicated fluoric gas; but when further diluted, this latter property ceases, and its action on glass is proportionably weakened and retarded. It is more conveniently employed in its diluted state for etching on glass, when its action is not apparent till after some hours.

A similar use of this acid is to destroy the polish of glass, which may be advantageously employed for lamp-shades.

When the sole object is to prepare a dilute acid, it will be done with much more convenience by distilling the pure fluor-spar and sulphuric acid in leaden vessels and receiving the product in a leaden vessel containing water.

Pure liquid fluoric acid acts with prodigious vehemence on potassium when a piece of this latter is dropped into the acid. A violent detonation takes place, so as to disperse the whole contents; but when the acid is gradually applied to the potassium enclosed in a tube full of azotic gas, the action is more moderate, and the products can be collected. They are, chiefly, a very large quantity of hydrogen gas, and a transparent liquid, which soon crystallizes in the air into *acid fluat* of potash. Hence the authors conclude that the most concentrated fluoric acid contains a portion of water, that when this unites with potassium the water is decomposed, its hydrogen appears in its simple form, and its oxygen converts the potassium to potash, which then unites with the acid into fluat of potash. If this explanation be just, the potassium does not decompose the fluoric acid, but only the water with which it is united, when liquid.

Alkaline and Earthy Fluats. Neutral fluat of potash was made by direct combination of

the acid and alkali. This neutral salt is very deliquescent, has a pungent taste, and is not easily crystallized. Sulphuric acid decomposes it even when cold, with much effervescence and disengagement of vapour. Lime-water, strontian and barytic water, and the neutral solutions of barytes, strontian, lime, magnesia, alumine, glucine, yttria, and zircon, when poured into a solution of fluat of potash, all produce a precipitate of the fluoric acid and the base employed.

When silicated fluoric acid gas is passed into water a copious precipitate takes place, which consists of an acidulous fluat of silex, and there remains in solution a very acid fluat of the same earth. If caustic potash is added to the latter solution, a nearly insoluble salt is formed, which is a triple compound of fluoric acid in a little excess, of potash and of silex. So nearly is this salt insoluble that the supernatant liquid scarcely leaves any residue when evaporated to dryness. This triple salt is in the form of a transparent jelly, nearly tasteless, but reddens litmus, and may be dried without decomposition. At a red heat and also by sulphuric acid in the cold it is decomposed, and gives out common silicated fluoric gas. An excess of alkaline solution dissolves this triple salt if heated.

Soda combined directly with pure fluoric acid, forms a hard salt in small crystals, which is somewhat more soluble in hot than in cold water. It neither deliquesces nor effloresces. Sulphuric acid decomposes it with strong effervescence of fluoric acid gas. The simple solutions of the earths and also the soluble earthy salts form insoluble precipitates with this salt, consisting of the fluoric acid and the base employed.

Soda appears to act upon silicated fluoric acid in a very different manner from potash, for instead of only partially decomposing this compound, and forming triple silicated salts, it totally separates the silex, when at a boiling heat, in a gelatinous form, and the liquor separable by filtration is pure fluat of soda, not differing from the salt made by the direct union of the pure acid and soda.

Fluat of ammonia formed by the pure acid and liquid ammonia, though neutral at first, becomes acidulous by evaporation, part of the alkali volatilizing, and then is incapable of crystallizing, and finally evaporates totally in white fumes. When liquid ammonia is added in excess to silicated fluoric acid, much of the silex separates as a white opaque jelly, and is the

pure earth uncombined with any portion of acid. The supernatant liquor is a triple compound of fluoric acid, silex, and ammonia, which becomes acidulous by evaporation, and then a fresh addition of ammonia separates more silex; and this alternate evaporation of excess of ammonia and precipitation by fresh alkali, may be repeated a number of times on the same materials. Hence the fluat of ammonia can only be made by the direct union of the pure acid and ammonia; but pure silex may be extracted from the silicated fluoric acid by means of this alkali.

Pure fluoric acid causes a flocculent precipitate in barytic water, which an excess of the same acid or of the nitric or muriatic acids, will redissolve. The same barytic fluat is produced by adding fluat of potash or soda to any soluble salt of barytes. But when any of these barytic salts is added to the silicated fluoric acid, after some minutes, a quantity of very hard small crystals falls down, which are insoluble in water or acids, and are a triple salt of fluoric acid, barytes, and silex.

The compound salt of fluat of silex and fluat of lime, or triple compound of fluoric acid and these two earths, probably exists native, for there are many specimens of fluor spar which appear quite uniform and transparent, but yet give the silicated fluoric acid, and not the pure acid, when distilled.

Fluoric acid diluted with six or seven parts of water dissolves zinc rapidly, and with disengagement of much hydrogen. The solution at first remains clear owing to the excess of acid, but after a time the fluat of zinc separates almost totally in white flocculi. The same salt is made immediately by adding fluat of potash to sulphat of zinc. This fluat is tasteless, insoluble in water, but readily dissolves in nitric, muriatic, or its own acid. It cannot be crystallized.

The habitudes of iron with fluoric acid much resemble those of zinc, only the fluat of iron is much less easily soluble in an excess of its own acid.

Fluoric acid moderately concentrated, does not act upon metallic tin cold or hot, but it readily dissolves the peroxyd of this metal. This salt may be evaporated to dryness without being sublimed, in which it differs from the muriat of tin.

The suboxyd of tin is also soluble with ease in fluoric acid. When evaporated by itself with contact of air, it becomes oxygenated, and is changed to the last-mentioned salt; but evapo-

rated in contact with tin filings, it remains unchanged, and very brilliant white acid crystals of fluated suboxyd of tin are formed.

Metallic copper is not attacked by fluoric acid, even with only twice its weight of water, but the oxyd of copper easily dissolves, and small blue acid crystals are produced.

Fluoric acid easily dissolves the oxyd of silver, and the salt has a very strong metallic taste, is highly soluble in water and deliquescent. It is not volatile by heat, but fuses like luna cornea, losing thereby its excess of acid, but remains soluble. It cannot be crystallized. It stains the skin black. The fixed alkalies and earths decompose it, but not ammonia. Metallic silver is not acted on by this acid, but it is readily dissolved by heating fluated peroxyd of mercury with silver. Fluat of potash does not precipitate nitrat of silver.

Lead is only acted on by fluoric acid when oxydated. Fluat of lead is readily formed by fluat of potash and acetite of lead. It precipitates in white flocculi, which become brilliant laminae after washing. It is insoluble in water, but readily dissolves in nitric, muriatic, or fluoric acids. It melts at a low red heat, and turns yellow, losing part of its acid.

Metallic mercury resists fluoric acid, but the red oxyd dissolves in it when moderately diluted and boiled in a platina vessel. This salt is in small yellow lamellar crystals, but it forms with difficulty, and requires a great quantity of the acid. These crystals totally exhale when strongly heated. They are acid, but, when washed with water, a part of the salt dissolves along with most of the excess of acid, and the remaining salt becomes of a deep orange or red. In this separation by water into a soluble acid salt, and an insoluble neutral salt, the fluat of mercury agrees with most of the other highly oxydated mercurial salts.

The authors of this interesting memoir then proceed to describe other properties of the fluoric acid, and in particular a very singular compound of this with the boracic acid which they have discovered, and to which they give the name of *Fluoboracic acid*. But before we proceed with this part of the subject, we shall notice a valuable paper on many of the properties and compounds of fluoric acid by Mr. J. Davy, whose experiments appear to have been made nearly at the same time with those of the French chemists above described, though not published so soon.^b

Pure fluoric acid, as Mr. J. Davy observes,

has never yet been obtained in a gaseous state, and only two substances have hitherto been known to have the power of uniting with it into a permanently elastic gas, namely, silex and boracic acid. The former substance makes the well known compound first discovered by Scheele, and to which the term *Silicated Fluoric Gas* is properly applied. It is difficult, as already mentioned, to avoid obtaining this gas in treating fluor spar with sulphuric acid, unless a very pure fluor be chosen and metallic vessels used. It is conveniently prepared by adding pounded glass to the spar and acid, and by this means the glass retort may be saved for a future operation. This gas is perfectly saturated with silex, for it may be long kept under glass vessels without taking off their polish. A hundred cubic inches of this gas at a medium pressure and temperature, weigh 110.78 grains, or about three times as much as common air, of which 100 cubic inches in similar circumstances weigh 36.45 grains.

To analyze silicated fluoric gas, Mr. J. Davy caused 40 cubic inches of it to be absorbed by liquid ammonia, and obtained from it 27.2 grains of pure silex, after fulledulcoration and ignition. Supposing the remaining weight of the 40 cubic inches to be fluoric acid, (and therefore the whole of the silex to have been separated by the ammonia) it would amount to 17.1 grains, and hence silicated fluoric gas would contain

61.4 Silex
38.6 Fluoric acid

100.0

This gas is partially and unequally decomposed, by the action of water, into a precipitate of much silex and a little acid, and a liquid containing much acid and little silex. This liquid is properly termed by Mr. D. *Subsilicated Fluoric Acid*. To analyze it, Mr. D. assumes that the precipitate formed by the absorption of silicated fluoric gas in water, is mere silex, and that the whole of the acid remains in the solution, (which is contrary to the opinion of Gay Lussac) and hence the *Subsilicated Fluoric Acid* differs from the former only by the quantity of silex separated on its absorption by water. It is therefore thus composed.

54.56 Silex
45.44 Acid

100 00

^b Phil. Trans. for 1812. part 2.

Water, Mr. D. finds, will absorb and decompose about 263 times its bulk of silicated fluoric gas by direct experiment. Dr. Priestley found that when muriatic gas is admitted to water that has absorbed the fluoric gas, the former is totally absorbed, and the latter resumes its original gaseous state, taking up with it the silex which had been separated by the water. The liquid that remains is simple muriatic acid. Sulphuric acid has the same effect as the muriatic in expelling silicated acid from water by which it had been absorbed. In either case, much effervescence takes place in proportion as the silicated gas resumes its gaseous form.

The liquid subsilicated acid does not appear to corrode glass vessels in which it is kept.

Silicated fluoric gas, like carbonic gas, condenses twice its volume of ammoniacal gas when the two are mixed over mercury: and they unite only in these proportions, whatever excess of either gas be employed. The result is a dry salt, containing according to Mr. Davy, 24.5 per cent. of ammonia, and saturated with silex: this salt is decomposed by water as the silicated fluoric gas is, the same proportion of silex being separated, and the liquid residue being a subsilicated fluat of ammonia, of which the alkali amounts to 28.34 per cent. This salt, obtained by slow evaporation, is in the form of brilliant tetrahedral prisms, very soluble in water but not deliquescent, and subliming unaltered by heat. It just reddens litmus. Mr. Davy observes, that if the concentrated solution of this salt is evaporated in glass or earthen vessels, it powerfully erodes them if heated to the boiling point, as is shewn by a deposition of silex on dilution with more water.

The sulphuric acid decomposes the subsilicated fluat of ammonia, expelling silicated fluoric gas. Potash also decomposes it, expelling the ammonia, and forming subsilicated fluat of potash.

Contrary to the experience of Messrs. Gay Lussac and Thenard, Mr. J. Davy finds that an excess of ammonia separates the whole of the silex from the subsilicated fluat of ammonia, and the remaining liquid furnishes by evaporation in metallic vessels a simple fluat of ammonia, containing 76.4 of alkali, and 23.6 of pure fluoric acid, besides water of crystallization. This fluat thus formed is quite neutral, and deliquesces in the air. When heated somewhat above the boiling-water point, a part of the ammonia flies off, leaving a salt with excess of acid behind. When the heat is further raised, the whole salt sublims in very pungent fumes,

highly dangerous to respire. If this be done in a glass vessel it is strongly corroded, and the salt is now converted to silicated fluat. Indeed the action of this simple fluat of ammonia is so strong on glass, that a little of the solution pencilled on and moderately warmed, will speedily produce an etching.

FLUOBORACIC ACID.

This name has been given by the discoverers, Messrs. Gay Lussac and Thenard, to a singular gaseous acid, a compound of the fluoric and boracic. These chemists finding that the pure fluoric acid, obtained from fluor spar and sulphuric acid in the manner described in the foregoing article, though a highly concentrated liquid, was probably combined with a portion of water (as concentrated sulphuric acid itself is) endeavoured to expell the fluoric acid pure, dry and gaseous, from fluor spar by the action of another acid, which could not be suspected to contain any water in its composition. The vitrified boracic acid was selected for that purpose, and on distilling it in a strong heat with fluor spar, it was found that the fluoric acid was indeed expelled in a perfectly dry state, but that in the process it became united chemically with a portion of boracic acid, which it thus volatilized, and retained as a permanently elastic gas, in the same manner as silex is gassified with fluoric acid when fluor spar, glass and sulphuric acid are distilled together.

Therefore, though these ingenious chemists failed in their object of producing a pure gaseous fluoric acid, they have discovered a new gaseous compound of fluoric and boracic acids, which has several remarkable properties.

The fluoboracic acid is thus prepared. Take the lower end of a gun-barrel with the touch-hole plugged up, coat it with good fire lute, put into it a quantity of very pure fluor spar mixed with half its weight of pure vitrified boracic acid, both reduced to powder; lute on the end of the barrel a bent glass tube; put the barrel into a furnace so that the open end projects, and let the extremity of the glass tube dip under a jar full of mercury. When the heat is raised to full redness, the acid gas is expelled in dense vapours, and as soon as they are totally absorbable by water, the gas is pure and may be collected under mercury.

This compound acid gas is a colourless permanently elastic fluid; its smell is pungent; it extinguishes light instantly, and powerfully reddens blue vegetable colours. When this gas comes in contact with any air containing hygrometric moisture, it condenses in thick white

fumes, but it mixes uniformly with dry air, and hence it is an excellent test of hygrometric moisture. It has no action whatever on glass. It corrodes vegetable and animal matters as powerfully as the strongest sulphuric acid, and carbonizes them, so that it instantly blackens paper.

It converts alcohol into ether. It does not however corrode the skin whilst experiments are made upon it. Water appears to dissolve at least as much of this gas as of muriatic acid gas, and at the same time the water heats and expands much.

When it is saturated it forms a limpid fuming caustic liquid, which when heated will give out only a fifth of the gas that it had absorbed, and it then resembles strong sulphuric acid in causticity and in appearance, and like this acid its boiling point is very high, and when distilled by itself, it condenses in long streaks on the receiver.

The fluoboracic acid combines very easily with the various salifiable bases. When saturated with ammonia and when the solution is evaporated to dryness, a higher heat expels a white sublimate of fluat of ammonia mixed with some borate of ammonia, and pure fused boracic acid remains behind.

These chemists did not pursue the examination of these compounds much further, except to ascertain that the fluoboracic gas is not altered by passing through red-hot iron turnings.

Mr. J. Davy (in the paper above quoted) finds that this compound acid gas may be procured in an easier manner than that just described. It is sufficient to heat gently in a common glass retort, one part by weight of fused boracic acid mixed with 2 parts of fluor spar, both in fine powder, and about 12 of sulphuric acid. Common calcined borax will even answer, but not so well. If the heat is gentle the retort will be untouched, and pure fluoboracic gas will be produced. If the heat be raised higher, a viscid mixture of sulphuric and fluoboracic acid comes over. Not more sulphuric acid should be used than is necessary to decompose the fluor spar, on account of the quantity of the fluoboracic gas which is absorbed by the sulphuric acid. The specific gravity of this gas, Mr. J. Davy estimates to be to that of common air, as 14.7 to 6.2, and hence 100 cubic inches weigh 73.5 grains. Water condenses no less than 700 times its volume of this gas, which is more than of any other known gas. Water thus fully saturated has 1.77 specific gravity. Sulphuric acid condenses about 50 times its volume

of the gas, and forms a dense tenacious compound.

Some singular results take place on combining the fluoboracic gas with ammoniacal gas. When equal volumes of the two gasses are used, they condense into a solid white opaque salt. When a double or triple quantity of ammonia is employed, the dry salt resolves itself into a transparent colourless fluid, though without containing any water.

Decomposition of Fluoboracic and Silicated Fluoric Gas.

The singular energy of potassium in depriving most oxyds of their oxygen, and leaving their bases separate, has been employed to discover the hitherto unknown radical of fluoric acid. But here a particular difficulty occurs, as no means have yet been found of obtaining fluoric acid free from water, except by combining it with silex or with boracic acid in the form of gas. As the presence of water entirely defeats the purpose of applying potassium, it is necessary to take the other alternative of employing one of the two compound fluoric gasses.

Messrs. Gay Lussac and Thenard have examined the effect of potassium on both these gasses.

Potassium is not sensibly acted on by dry silicated fluoric gas at a common temperature, but if it is melted in the gas by a gentle heat, it thickens and burns strongly with much light and heat. In this process a large quantity of the gas is absorbed, very little hydrogen is given out, and the potassium is converted into a reddish brown substance. When this latter substance is digested with hot water, some hydrogen is given out, the hot water holds in solution some fluat of potash; and the insoluble portion, after calcination in an open crucible or combustion in oxygen, yields a triple fluat of potash and silex. From these facts the authors conclude, that the potassium when burned in silicated fluoric gas, decomposes the fluoric acid, and that the reddish brown substance is a compound of *fluoric radical*, potash, and silex, and perhaps some undecomposed fluoric acid, and hence when it is afterwards digested with water, the fluoric radical returns to the state of fluoric acid, and forms with the potash and silex an insoluble fluat of silex and potash. Potassium burns with great ease in this gas, and when only a small quantity is used, it may be done in a small glass tube full of the gas, into which the potassium is introduced on an iron support, and heat applied externally by a spirit lamp. Sodium

has a similar action on this gas to that of potassium.

Potassium is equally combustible in the fluoboracic gas as in the silicated gas, and nearly with similar appearances. The residue after combustion is chocolate coloured solid unmetallic in appearance, with very little taste and fusible at a cherry red heat. When thrown into water, hot or cold, it gives out only a few bubbles of hydrogen and a portion dissolves. This portion is mere fluat of potash, for it is precipitated by the watery solutions of lime, barytes, and strontian, and also by the soluble salts of these earths; and moreover when evaporated to dryness, the salt gives much fluoric acid vapour with sulphuric acid, and sulphat of potash is left. On the other hand, the insoluble portion of the product of potassium burnt in fluoboracic gas is a dark coloured insipid infusible substance, which easily decomposes nitric acid, and is thereby converted to *Boracic acid*. It is equally changed to this acid when burnt in the open air or in oxygen gas, and when deflagrated with nitre, it yields borat of potash. From all these circumstances, they conclude that this chocolate-brown insoluble portion is the *Boracic Radical*, or *Boron*, probably combined with a little fluoric radical.

Similar experiments to those just mentioned have been performed by Sir H. Davy,* with results that correspond in a very great degree. When silicated fluoric acid gas is introduced into a plate-glass retort, exhausted after being filled with hydrogen gas, and potassium is added, white fumes are perceived, and the metal becomes covered with a greyish crust. These do not materially encrease while the heat is kept moderate, and no change will be found in the gas, except by the addition of a small quantity of hydrogen. But if the heat be raised to the sublimation of potassium, the metal rises through the crust and kindles, burning with a most brilliant red light. If the potassium is in sufficient

quantity, all the fluoric gas is consumed, and hydrogen alone remains, which does not exceed a tenth of the fluoric gas if previously dried. A chocolate coloured mass is left in the retort. This substance effervesces violently in water, giving out an inflammable gas. When a portion of it is heated in the air, it burns slowly, and even in oxygen with difficulty. The final product of the combustion of this mass and of its solution in water, is fluat of potash with silix.

The same eminent chemist also employed a fluoric gas free from silix by heating fluor spar and boracic acid in an iron tube, and of course obtained the fluoboracic gas, but in this experiment the gas was decomposed by potassium as soon as formed. The result was a dark brown combustible mass, affording the fluoric and boracic acids after combustion. Hence he infers it to be probably a compound of the two bases of these acids, or rather of their oxyds.

The general inference from all these last related experiments of the action of potassium on the compound fluoric gasses, certainly gives probability to the opinion of the existence of a *Fluoric Base*, or *Radical*, but this base has never been obtained separate, as it is combined, in all probability, with the base of silix in one instance, and the base of boracic acid in the other. Other attempts to insulate the fluoric acid by distilling fluor spar with vitreous phosphoric acid have equally failed, and even were this difficulty surmounted, it would still be not easy to contrive a mode of unexceptionable analysis, owing to the powerful action which this acid exerts on the silix which enters so largely into the composition of every kind of glass vessel.

Fluor Spar has been analyzed both by Klaproth and Dr. Thompson. Dr. T. finds no more than $\frac{1}{800}$ of its weight of water, and the ignited spar contains about $67\frac{1}{2}$ per cent of lime, and $32\frac{1}{2}$ of acid. Klaproth's analysis gives nearly the same result.

G

GABBRONITE.

The colour of this mineral is grey, with different shades of bluish and reddish. It occurs massive; is harder than glass, but does not readily give sparks with steel. It is translucent on the edges; is of a very compact texture, and when broken, exhibits a splintery fracture. Before the blowpipe, it melts with difficulty

into a white opaque globule. It has not as yet been analyzed, but as far as may be judged from external characters, is but little different from compact felspar.

It has hitherto been found only in Norway, accompanied by octohedral iron ore, red compact felspar, hornblende and talc.

* Phil. Trans. for 1809, p. 85.

GALLIC ACID.

In our former article we described Scheele's original process for preparing this acid, and also Deyeux's method by sublimation. Mr. Richter has given a different process, by which this acid is prepared in very considerable purity. It is the following.^a Make a cold infusion of finely powdered gall-nuts in water, frequently stirring it, then strain the whole through a cloth, and press the residue strongly to get out the whole infusion. Evaporate the liquor to dryness with a very gentle heat, which will leave a dark brown brittle mass. Reduce this to a fine powder and digest it with very highly rectified alcohol, added twice successively. The first tincture thus prepared will have a weak straw-colour; the second will be nearly colourless. The undissolved part is tannin almost pure. Mix both the spirituous tinctures, and distill it in a retort till only an eighth part is left. Add water to the residue in the retort and warm it, and then reduce it by evaporation, and small white crystals will separate, as long as any mother liquor remains. These crystals are the Gallic Acid. One pound of galls will give about half an ounce of these crystals.

This acid certainly contains a smaller admixture of tannin than that prepared in Scheele's method; for tannin is scarcely at all soluble in alcohol, whereas gallic acid is highly so, but the alcohol here employed should be very highly rectified. This acid when added to a perfectly clear and neutral solution of sulphat of iron does not produce any change till the iron has absorbed an additional portion of oxygen from the atmosphere. In this respect it differs from Scheele's acid, or from the simple infusion of galls, which immediately gives a purple hue to the neutral sulphat of iron. Richter therefore supposes, with some probability, that the tannin in this case unites with the sulphuric acid, and detaches a portion of oxyd of iron to unite with the gallic acid.

Bouillon La Grange has given a valuable comparative view of the shades of difference in these acids, with some remarks on the intimate nature of gallic acid.^b Berthollet having proposed the oxyd of tin as a method of freeing the common brown gallic acid from its adhering tannin or extract, La Grange has examined this process, and finds that by evaporating a solution of this brown acid in contact with a certain quantity of the oxyd of tin, and then again diluting with water, the acid still gave a precipitate with animal jelly, though

slightly, and the solution when crystallized furnished a gallic acid of greater purity than before. But on repeating the process with a fresh portion of the oxyd of tin, the solution was now so entirely decomposed as to be clear and colourless, to give no precipitate either with sulphat of iron or with jelly, and to yield no crystallized acid on evaporation.

The red oxyd of mercury when long boiled with the gallic acid, finally decomposes both the pure acid as well as the tannin.

Charcoal recently calcined, when boiled with gallic acid, deprives it of its peculiar taste, gives it a green colour, and takes away its property of precipitating jelly; and a greater proportion of charcoal destroys the acid altogether.

All these experiments shew the impossibility of obtaining gallic acid free from the tannin except by sublimation, but it remains to be shewn whether the sublimed acid is identical with the mere acid part of the crystallized acid. M. La Grange has contrasted the differences between these two acids. The sublimed acid, he observes, has less acidity, it is decomposed in the air, it has no action on barytes, or carbonat of ammonia, or on muriat of tin; the precipitate obtained by nitrat of mercury is blackish instead of being yellow, and that by acetite of lead is yellow and scanty, instead of being white: oxymuriatic acid renders it brown, whereas it does not change the colour of the crystallized acid. The sublimed acid does not precipitate animal jelly.

In continuing these experiments both on the acid and on the gall nut itself, the author uniformly obtained a quantity of acetous acid by the distillation of all these varieties of gallic acid, whence he is led to the conclusion that the acetous acid is the real acid basis of the gallic acid, as well of most other supposed individual vegetable acids, and that its peculiar characters are masked by volatile or fixed empyreumatic oils, by tannin, by extract, or by other vegetable principles with which it is capable of entering into intimate combination.

GLAUBERITE.

The colour of this mineral is wine yellow of greater or less intensity: it occurs only crystallized, in the form of an oblique prism with rhombic bases. The faces of the base are smooth and brilliant, those of the sides are striated parallel to the edges of the base. It presents natural joints in two directions, namely parallel to the base (and these are the easiest

^a Ann. Chim. tom. 52.

^b Ann. Chim. tom. 60.

to observe) and inclined upon the former at an angle of 104° .: in other directions the fracture is vitreous. It is transparent, in hardness between gypsum and calcareous spar. Sp. gr. 2.73.

On immersion in water it becomes opaque, and is the only mineral exhibiting this character. Before the blowpipe it decrepitates, and then melts into a white enamel. It is in part soluble in a moderate quantity of water, and entirely in a large quantity of the same fluid. It appears to contain no water of crystallization, but is composed of

49. sulphate of lime

51. sulphate of soda

100

It occurs at Ocagna, in New Castille, disseminated in rock salt, and was first discovered by M. Brongniart. (*Journ. de Mines*,) xxiii. page 5.

GOLD.

A remarkable difficulty attends the analysis of the salts and oxyds of gold, which has not yet been got over in a satisfactory way, though several apparently accurate series of experiments have been undertaken on this subject, particularly of late by several French chemists, now that an attempt has been made to restore gold to its ancient place as an important article of the materia medica.

Two difficulties oppose the accurate estimation of the proportion of oxygen with which gold unites in its salifiable compounds: one of them is that no alkali or single base will precipitate the whole of the oxyd of gold in a given portion of its muriatic solution, and hence the usual way of dissolving a given portion of any metal, and of finding the quantity of oxygen in its oxyd by the encrease of weight in the total precipitate over that of the metal employed, cannot be used with the salts of gold: the other difficulty is the readiness with which the oxyds of gold return, either totally or partially, to the metallic state, so that of any given portion of precipitated oxyd, one part will often become reguline in the common way of drying, and thus defeat the purpose of analysis. To these difficulties may be added that of the solubility of the simple oxyd of gold in water, so as to render edulcoration an uncertain operation, and one attended with loss.

We shall add a few particulars concerning

the salts and compounds of gold from Proust,^a Vauquelin,^b Duportal^c and Oberkampff.^d

The most powerful aqua-regia for dissolving gold, according to Vauquelin, is composed of two parts of muriatic acid to one of nitric acid, both concentrated, and this nitro-muriatic acid will dissolve by boiling about a third of its weight of pure gold. Proust employs a greater proportion of muriatic acid. When the acid has dissolved as much gold as it will take up, the solution is still very acid. If it is evaporated sufficiently, it yields yellow prismatic crystals of muriat of gold, particularly if an excess of gold be kept in the liquor. This muriat is highly deliquescent, becoming fluid in a warm day and solid again in a cold one. The taste is acerb and bitter. When moderately heated, oxymuriatic acid is given out, and the gold remains in the metallic state, but spongy, and without lustre. A part however of the gold is volatilized with the acid.

The action of potash on the solution of gold in nitro-muriatic acid has been examined with peculiar attention. When caustic potash is added to the solution in the cold, it becomes of a deep red, but no turbidness whatever ensues, even on keeping it for a length of time. But if after the solution is saturated with potash it is heated to boiling, a bulky red flocculent precipitate falls down. The supernatant liquor is then colourless, but if it is again supersaturated with muriatic acid it resumes its original yellow colour and will still give a copious precipitate of gold on adding tin, or sulphat of iron. Potash therefore will not separate the whole of the gold, nor probably much more than half of it, as it was found that 72 grains of gold in solution only yielded 40 of the oxyd by adding potash. The reason of this imperfect separation appears to be the great tendency of muriat of gold to form a triple salt with muriat of potash, (and it is the same with the other alkaline or earthy muriats) which triple salt is very soluble, and not further decomposable by any excess of alkali, when the metallic salt does not exceed a certain proportion of the whole. For this reason too, the quantity of precipitate obtainable by potash is in a reverse proportion to that of acid present, so that where the acid is in great excess, no separation will take place on adding any quantity of potash, as the muriat of potash will then be sufficient to hold all the muriat of gold in triple combination.

^a Journ. de Phys. tom. 62, or Phil. Journ. vol. 14.

^b Ann. Chim. tom. 77.

^c Ibid. tom. 78.

^d Ibid. tom. 80.

If the precipitate by potash is washed and dried in the gentlest heat, it is not however an uniform oxyd of gold, as might be expected, but a portion returns to the metallic state, so that the powder is a mixture of reduced gold and of its oxyd. These however may be separated by pure muriatic acid, which dissolves out the oxyd and leaves the reguline part untouched. The precipitate from the muriat of gold, by potash either caustic or carbonated, appears also by Vauquelin's experiments to carry down with it a portion of muriatic acid, since the washings long continue to curdle nitrat of silver. The oxyd itself indeed is also slightly soluble in hot water even when all the muriatic acid is washed out, so that by a succession of edulcorations by far the greater part of the entire precipitate may be washed away. No carbonic acid appears to enter this precipitate though a carbonated alkali be employed.

The clear liquor remaining after the separation of the oxyd of gold from its muriatic solution by potash, becomes yellow on saturation of the alkali by the same acid, and shews the presence of gold by adding sulphat of iron or tin. When slowly evaporated it yields crystals of simple muriat of potash, (shewn to contain no gold by not turning yellow with muriatic acid) and the triple muriat of potash and gold above mentioned. If carbonated potash was used to precipitate the oxyd, some crystals of this salt also are formed.

Vauquelin relates that the Paris jewellers were ignorant of the fact that alkalies will not precipitate the whole of the gold from its solution, and therefore were in the habit of incurring a very great loss of this precious metal by taking no care of the washings when this mode of employing gold was used.

Oxyd of Gold. Mr. Oberkampff endeavoured to ascertain the proportions of the dark brown oxyd separated by potash from the muriatic solution, by enclosing a portion of it, still wet, in a bent glass tube closed at one end, heating it till the whole was reduced, and estimating all the products. The oxyd was not dried, to avoid the partial reduction that takes place, and it was totally soluble in muriatic acid, and therefore unmixed with any reguline gold. The results of three experiments gave 100. of metal with 9.82, with 10.21, and 10.6 oxygen. The mean of the three is 10.01 oxygen, which would make 100 parts of the oxyd to consist of 90.9 gold, and 9.1

oxygen, but the difference between the highest and lowest estimation being nearly a tenth, this can only be considered as a tolerable approximation to accuracy.

It is highly probable that this is the *peroxyd* of gold, and if there is any lower state of oxygenation it must be looked for in the purple powder to which gold is reduced by combustion, either by means of a powerful electric or galvanic apparatus, as described in our former article.

Professor Berzelius, whose authority must always carry much weight, has given a somewhat different view of the oxydation of gold, but at present we only have a short extract of his experiments.^e He observes that the muriat of gold has two degrees of saturation. With excess of acid it forms yellow needled crystals, and the base of this is the peroxyd of 12.077 oxygen to 100 of metal. When this is perfectly neutral it is of a deep orange colour. If this latter salt is heated till it no longer gives out oxymuriatic gas, a saline mass insoluble in water is left, which is a muriated *suboxyd* of gold, and when decomposed by potash gives a green suboxyd containing only 4.026 of oxygen to 100. of metal. This suboxyd however exists but a few moments as such, being speedily reduced to metallic gold and peroxyd. As this proportion of oxygen is only a third of that of the suboxyd, the author conjectures that an intermediate definite oxyd must exist, which possibly may be the purple powder of Cassius, or the purple oxyd formed on many occasions with the salts of gold and animal or vegetable matters. As no particulars of the experiments are given, we are unable to state the many difficulties which immediately occur with regard to these positions.

Purple precipitate of Cassius. The mode of preparing this very singular compound has been amply described in our original article, but we shall add some very ingenious conjectures of Proust on the nature of this compound. It is prepared, as is well known, either by adding a solution of muriated suboxyd of tin to the muriat of gold, or by immersing in the solution of gold some pieces of metallic tin. When this powder is digested in nitro-muriatic acid, it loses its colour, gives a yellow solution of gold, and leaves a heavy sandy transparent peroxyd of tin. Muriatic acid assisted by heat has the same effect. Hence one of the component parts of this powder is peroxyd of tin. The other is gold, but it has been doubted.

^e Ann. Chim. tom. 83. p. 166, being an extract from a memoir given to the Stockholm Academy.

whether, besides metallic gold, any portion of it is in the state of oxyd. That the oxyds of tin and gold are united by some kind of affinity, and not merely mechanically mixed seems proved by the following facts: the purple powder is perfectly soluble in liquid ammonia, forming a vivid purple liquor; but the metallic precipitates of gold are not so soluble in ammonia, and the oxyd of tin is but imperfectly so: also mercury, which so readily takes gold from most other combinations, has no effect on the purple powder though shaken with it. A hundred grains of the purple powder digested with weak aqua regia, gave, by Proust's experiments, a solution of gold, from which sulphat of iron separated 24 grains of metallic gold. The remaining peroxyd of tin weighed 70 grains, and hence 6 grains of the peroxyd must have been dissolved in the acid along with the gold. Therefore the gold in this preparation unites with about three times its weight of oxyd of tin. By the experiments of Duportal it appears that the degree of dilution

much influences the quantity of this precipitate, so that when a very weak solution of gold and of muriat of tin are employed, one part of gold will produce as much as $5\frac{1}{2}$ parts of the purple precipitate.

The sulphated suboxyd of tin will also produce the purple precipitate with the solution of gold.

GREEN-EARTH.

There have been two recent analyses of this substance, one by Klaproth and the other by Vauquelin, the results of which are as follows.

K.	V.	
53.	— 52.	sillex
2.	— 6.	magnesia
28.	— 23.	oxide of iron
10.	— 7.5	potash
0.	— 7.	alumine
6.	— 4.	water
99.	— 99.5	

II

HARMOTOME. Kreuzstein, W. Cross stone, Jam.

The colour of this mineral is white, semi-transparent, with a shining lustre between vitreous and pearly. It occurs only crystallized, in broad tetrahedrons with rhombic pyramidal terminations, hence the entire crystal may be considered as a dodecahedron. The crystals are either single or cruciformly aggregated, intersecting each other at right angles, so that the axes of the two crystals coincide. Its hardness is somewhat superior to that of glass: its fracture at right angles to the axis of the crystal is uneven and small conchoidal, in other directions it is foliated. Sp. gr. 2.3. Becomes phosphorescent by heat, giving out a greenish yellow light. Intumesces before the blowpipe.

The cruciform variety has been analysed by Klaproth, and the single crystals by Tassaert, with the following results.

K.	T.	
49.	— 47.5	Sillex
18.	— 16.	Barytes
16.	— 19.5	Alumine
15.	— 13.5	Water
98.	— 96.5	

The cruciform variety occurs in mineral veins

at Andreasberg in the Hartz, and at Strontian in Argyleshire; the single octohedrons have only been observed lining agate balls at Oberstein.

The only mineral likely to be mistaken for Harmotome is Jargoon in small dodecahedral crystals; the latter however is infusible before the blowpipe and possesses a specific gravity nearly twice as great as the former.

HYALITE. Muller glas.

This substance bears a perfect resemblance in its external appearance to gum Arabic. Its colour is greyish white or yellow, between translucent and transparent, with a vitreous lustre. It is harder than glass, breaks easily and with a flat conchoidal fracture. It occurs lining cavities and forming irregular botryoidal concretions in Wakke at Frankfort on the Mayn. It appears to be nearly allied to semi-opal.

HYDRARGILLITE. See WAVELLITE.

HYDROSULPHURET. See SULPHURETTED HYDROGEN.

HYPERSTENE.

The mineral designated by this name in the Tableau Comparatif of Haüy is the Labrador HORNBLENDE of the German and English mineralogists. Its external characters will be found on referring to the article Hornblende in the Dictionary; the crystallographical characters

which have induced M. Haüy to form of it a separate species are the following.

Primitive form, a rhomboidal prism the alternate angles of which are 100° and 80° ; with distinct joints in the direction of the short diagonal, and with others less distinct in the direction of the long diagonal. Sp. gr. 3.4. Its component ingredients, according to Klaproth, are

54.25	Silex
14.	Magnesia
2.25	Alumine
1.5	Lime
24.5	Oxyde of iron
1.	Water
—	—
97.50	—

I J

ICHTHYOPHTHALMITE. Fischangenstein, W. Apophyllite, H.

The colour of this mineral is very pale yellowish, redish or greenish, more or less transparent, and with a shining pearly lustre. It occurs massive, with a foliated structure, or crystallized in rectangular parallelepipeds approaching to the form of a cube or of a table, in the latter case the edges are irregularly bevelled and more or fewer of the solid angles are replaced. The cross-fracture is fine-grained uneven, the longitudinal is perfectly foliated. It has natural joints in three directions at right angles to each other, but of these only one is visible without the assistance of a strong light. Its hardness is a little superior to that of fluor spar, and it is very easily frangible. Sp. gr. 2.46.

When exposed to the flame of a candle it exfoliates; before the blowpipe it is fusible with difficulty into a white enamel; by digestion in cold nitric acid it breaks down forming a kind of jelly. It has been analyzed by Vauquelin and Rose with the following results.

V.	R.
51.	— 55. Silex
28.	— 25. Lime
4.	— 2.25 Potash
17.	— 15. Water
—	—
100.	97.25

It occurs at Hellesta in Sweden.

IOLITE. Dichroite H.

The colour of this mineral, when viewed by transmitted light in a direction parallel to the axis of the crystal, is an intense Prussian blue, and when viewed in the opposite direction is brownish yellow. It occurs in irregular aggregated grains, or crystallized in regular hexahedral prisms (its primitive form) or in dodecahedrons. Its hardness is a little greater than that of quartz; and it breaks easily, with a shining conchoidal fracture, passing into imperfectly lamellar. The crystals are usually translucent, the grains opaque. Sp. gr. 2.56.

VOL. III.

It melts with difficulty before the blowpipe into a very pale greenish grey enamel. It has not as yet been analyzed.

It has been found only at Cape de Gattes, imbedded in a peculiar kind of conglomerate.

IODINE.—See the addendum to this appendix.

IRON. § 1. Ores of.

An interesting examination of the brown and ochreous ores of iron has been published by M. Daubuisson (Jour. des Mines. xxviii. p. 443), from which it appears that these ores, which by mineralogical writers have been divided into several species wholly unconnected with each other, are in fact so closely related as to constitute a single species. The essential component ingredients of all the varieties of this species are, per-oxyd of iron and water, in the proportion of about 85 of the former to 15 of the latter. When scraped or pulverized they are of a brownish-yellow colour, which changes to red or redish-black by calcination. They contain casual and variable proportions, but upon the whole very small, of oxyd of manganese, carbonate and phosphate of iron, and silex and alumine.

The name given to this species is *Hydrate of Iron*, it being the only one of the ores of this metal into which water enters as a constituent part. Its varieties are the following.

Var. 1. Brown Hæmatite.

External form botryoidal or mammillated; colour chesnut-brown; texture fibrous; yields to the knife; sp. gr. 3.6—4.0.

Composed of 79. to 82. Peroxyd of Iron

15.	— 14. Water
2.	— 2. Oxyd of Manganese
3.	— 1. Silex

99. — 99.

Var. 2. Compact brown ironstone.

Amorphous; colour dark brown; fracture compact and even, often presenting small cavities; rather harder than var. 1. Sp. gr. 3.7.

Composed of	84. to 69. Peroxyd of Iron
	11. — 13. Water
	1. — 3. Oxyd of Manganese
	2. — 10. Silex
	0. — 3. Alumine
	98. — 98.

Var. 3. *Ætites*.

In concentric lamellar concretions from an inch to a foot or more in diameter; the external laminæ compact and moderately hard, but becoming softer as they approach the nucleus, which latter is often friable or loose ochre.

Composed of	76. to 78. Peroxyd of Iron
	14. — 13. Water
	2. — 0. Oxyd of Manganese
	5. — 7. Silex
	0. — 1. Alumine
	97. — 99.

Var. 4. *Pea ore*.

In grains or globular concentric concretions; yields to the knife. Sp. gr. 3.4.

Composed of	70. to 73. Peroxyd of Iron
	15. — 14. Water
	0. — 1. Oxyd of Manganese
	6. — 9. Silex
	7. — 0. Alumine
	98. — 97.

Var. 5. *Ochre*

Amorphous; colour yellowish brown; fracture earthy, soft or friable.

Composed of	83. Peroxyd of Iron
	12. Water
	5. Silex
	100.

Var. 6. *Bog ore*.

Amorphous, more or less cellular, the cells often lined with blue phosphate of iron; colour blackish brown; fracture uneven, passing into flat conchoidal; lustre resinous.

Composed of	64. Peroxyd of Iron
	19. Water
	7. Oxyd of Manganese
	6. Silex
	2. Alumine
	2.5 Phosphoric acid
	97.5

That variety of iron pyrites, usually called the radiated, has of late been formed by Haüy into a distinct species, by the name of "*Fer sulphuré blanc*,"^a *White Pyrites*.

Its general colour is considerably lighter than that of the common pyrites, being, when fresh and undecomposed, a perfect tin white, passing by decomposition into brass yellow and steel grey. Its primitive form is a rhomboidal prism, the alternate angles of which are 106°. 36' and 73°. 24'; its usual form however is the octohedron variously modified. It occurs in small crystals, but more usually in various particular shapes, such as reniform, stalactitic, &c. It gives fire with steel. Sp. gr. 4.75.

Before the blowpipe it gives out a light vapour with a sulphureous odour, and is afterwards attracted by the magnet; characters that distinguish it from arsenical pyrites, to which in colour and crystalline form it bears a great resemblance. It decomposes much easier than common pyrites into sulphate of iron.

§ 2. *Analysis of Iron and its Ores.*

Some important recent discoveries on this head deserve here to be mentioned.

Separation of Iron and Manganese.

Various methods of separating the mixed oxyds of these two metals have already been detailed in the articles IRON and MANGANESE, of the Dictionary: to these however may still be added the two following. It has been found by Berzelius and Hisinger,^a that benzoate of ammonia is equally efficacious with succinate of ammonia in separating iron from manganese. Benzoate of ammonia is prepared by neutralizing liquid ammonia with pure sublimed benzoic acid, and afterwards evaporating the liquor; during this last process, the salt will become acidulous, and in this state it is to be used, with the following precautions. The solution containing the mixed oxyds (the iron being in the state of peroxyd), is to be very accurately neutralized with ammonia, and to be considerably diluted; the benzoate is then to be added drop by drop, as long as any precipitate falls down; the whole being now thrown on the filter, a bulky pale redish-yellow mass is obtained: this, after repeated edulcoration with cold water (for in hot water it is more or less soluble) is to be dried at the temperature of boiling water, and is then pure benzoate of iron, containing 25 per cent. of red oxyd. If it is an object to save the benzoic acid, the metallic salt may be digested in liquid ammonia for some hours, by which it will be entirely decomposed; the alkaline

^a Journ. des Mines xxx. p. 241.

^a Stockholm Trans. or Phil. Mag. for 1812.

benzoate being contained in the solution, and the red oxyd of iron subsiding to the bottom of the vessel.

The method at present relied on by Vauquelin,^c as the most simple, and at the same time the most exact, is to digest the mixed oxyds in sulphuric acid, to evaporate the mass to dryness, and then to calcine it at a low heat, in order to decompose the sulphate of iron; the residue being now carefully washed with warm water, the whole of the sulphate of manganese in a state of perfect purity is taken up. From this solution the manganese is obtained in the state of oxyd, by means of carbonate of soda and subsequent calcination.

Separation of Manganese and Magnesia.

This is another of the practical difficulties in the analysis of the ores of iron. One way of effecting the separation of these substances is the following.

Having by means of caustic fixed alkali got rid of the silex and alumine, the residue insoluble in that menstruum is to be dissolved in sulphuric acid, and largely diluted; to this is to be added a solution of super-carbonated potash as long as any precipitate is formed. The precipitate consists of the metallic oxides, and the clear solution retains the lime and magnesia. This latter being then boiled, the sub-carbonates of the earths are deposited, and may be separated by the usual methods: their purity from iron or manganese is evinced by their retaining a white colour after calcination. Another method, recommended by Vauquelin, is to dissolve the mixed carbonates of manganese and of magnesia in acetic acid, and then to add hydrosulphuret of ammonia, which throws down the manganese, but has no such effect on the magnesia.

Hisinger's method is to calcine the mixed carbonates in order to separate the carbonic acid, to treat the residue by dilute sulphuric acid, which will dissolve the whole of the magnesia, and only part of the manganese; and then to add to the solution prussiate of potash, which will leave all the magnesia in the liquor, and separate only the manganese; after which the magnesia may be recovered by caustic potash.

It appears from a recent examination by Vauquelin,^d of certain bog-iron-ores, that besides the usual earths and iron and manganese, they contain phosphoric acid and oxyd of chrome. Thus the analysis is complicated by the addition of two more substances, and the practical difficulties of separating accurately all the ingre-

dients, are such as appear almost to have eluded the skill and resources of this truly eminent chemist. The following were the processes employed by him in the resolution of this problem.

The ore, previously pulverized, was fused with caustic potash and then digested in water, to which it communicated an intensely green colour. The portion insoluble in water was a second time treated with potash, and again digested in water. The two aqueous or rather alkaline solutions were added together and boiled, the green colour disappeared, and a brown precipitate was obtained, consisting of oxyd of manganese mixed with a little silex and oxyd of iron.

The solution, after separation of the manganese, was of a pale yellow colour indicating the presence of chrome; accordingly it was saturated with nitric acid, and a solution of nitrate of mercury made in the cold, was dropped in; a white precipitate was thus obtained, which on examination proved to be phosphate of mercury. The yellow colour of the solution having disappeared, and containing, on examination, an excess of acid, a few drops of caustic potash were added, which threw down a brownish red precipitate, consisting of chromate of mercury with a little phosphate. Into the solution, which was still acid, was dropped a little nitrate of silver, and immediately an orange coloured precipitate subsided, which did not give a green colour with borax, and was phosphate of silver. Potash was again added to the liquor, and occasioned a very voluminous lemon-yellow flocculent precipitate, which by drying acquired a green colour, and on examination proved to be chromate of mercury, containing silver and a little alumine and silex.

A somewhat different method was followed by the same chemist in his examination of the scorix produced in the fusion of the ore, which was the subject of the preceding analysis. The scoria was twice fused with an equal weight of caustic potash, and the portion thus rendered soluble in water, afforded a deep green solution, from which by boiling, the manganese was separated in the form of a brown oxyd. To the solution was now added nitrate of ammonia, which threw down a mixture of silex and alumine. The residual liquor was now slightly supersaturated with nitric acid, and boiled for a quarter of an hour, in order to separate entirely the carbonic acid. Lime water was then added, and a very pale yellow precipitate was deposited, which became green in drying, and on exami-

^c Journ. des Mines xxvii. 498.

^d Journ. des Mines xx. p. 382.

nation proved to be phosphate of lime, with a little chromate. Fresh nitrate of mercury was now poured in, and a brownish yellow precipitate fell down, which proved to be chromate of mercury with excess of base.

§ 3. *Reduction of Ores.*

One of the most important and successful enquiries on this head is the controversy that has arisen in France relative to the analysis and the general treatment of spathose iron; an ore which does not occur in this country in sufficient abundance to be made use of, but from which the celebrated irons of Styria and of the Tyrol, as well as those of various parts in the South of France, are entirely procured. The principal papers relative to this controversy, are contained in the *Annales de Chimie*, vols. lvi. lvii. lviii. lxii, and in the *Journal des Mines*, vol. xix. From these it appears that besides the carbonate of iron, which composes by far the greatest proportion of the ore in question, there is contained in it magnesia, varying in quantity from the smallest perceptible portion to nearly 14 per cent.; also the carbonates of manganese and of lime. The superintendents of the iron forges, where this kind of ore is manufactured, led by experience independently of any theory, have long been in the habit of sorting it into fusible and refractory ore. Of these the former may be made use of fresh from the mine, whereas the other is in its recent state excessively refractory, and requires exposure to the air for a space of from one to twenty years before it can be advantageously employed.

M. Descotils, who appears to have prosecuted this interesting enquiry with the most success, conceived that the difference between the two varieties, was principally, if not entirely owing to the magnesia. For this purpose he selected two varieties, one of which contained a considerable and the other only a very minute proportion of magnesia: from each of these he detached a portion, and subjected both to an assay at the same time, and in the same furnace. The former afforded a mass of minute metallic grains, which had not run together in consequence of the non-vitrification of the scoria; the latter on the contrary gave a perfectly formed and well melted button of metal. The result however was not quite conclusive, because this last variety contained a considerable quantity of manganese, to which its fusibility might be ascribed, another portion therefore of the same ore was freed from its manganese, and being submitted to the assay, yielded as perfect a but-

ton as the other; the only difference between them being that the former afforded a white and the latter a grey metal.

In a subsequent memoir on the same subject, M. Descotils pursues his researches into the power of magnesia to render refractory the most fusible ores of iron. A portion of the iron ore of Elba was submitted without any flux to a strong heat, and afforded a perfect button, while 100 parts of the same specimen, to which 15 parts of magnesia had been added, gave a precisely similar result to the assay of magnesian spathose iron. He also examined a specimen of refractory spathose iron, and found it to contain 4 per cent. of magnesia, and on comparing it with specimens of the same ore that had become fusible by exposure to the air, he found that this latter was almost wholly free from magnesia. Hence it appears that the material change operated on the refractory spathose iron ores by exposure to the air, either with or without a previous roasting, is the separation of the magnesia. With regard to the mode by which this separation is effected, it is obvious that where the ore contains pyrites, the decomposition of this will furnish sulphate of iron, which coming in contact with the carbonated magnesia, will be again decomposed, and the sulphate of magnesia hence resulting, will be washed away by the rain. In confirmation of this it was found that the washings of a heap of refractory ore that had been exposed for a long time to the air, actually afforded sulphate of magnesia with a little sulphate of lime. In those cases where the ore contains little or no pyrites, the magnesia appears to be rendered soluble by the excess of carbonic acid, which is continually escaping from the iron as it becomes more oxygenated.

§ 4. *Physical properties of Iron.*

In addition to those properties already mentioned in the Dictionary, it may be stated as a recent discovery, and one likely to be productive of much practical utility, that cast iron when heated yields readily to the saw.*

The precautions required in this operation are, that the piece of iron should be heated equally, for which purpose a reverberatory furnace is much better than a forge fire: That the temperature should be as high as the iron can bear without becoming pasty, in which latter case the teeth of the saw are obstructed, and the work proceeds slowly: That two saws should be made use of if the piece to be cut is of any considerable thickness, working with the first till it grows hot, and then employing the second

* *Ann. de Chim.* lxxxii. p. 218.

while an assistant is cooling the first in water and drying it: That the saw should be worked rapidly, steadily, and at full length. These precautions being duly observed, cast iron may be cut by a common saw with the same ease as dry box-wood, and without injury to the tool.

§ 5. *Chemical properties of Iron.*

In the articles *Sulphuret and Affinity* in this Appendix, we have given some observations on the different sulphurets of iron, natural and artificial, in addition to the very full notice of the subject in our original article *Iron*. We shall only here relate the particulars of Berzelius's experiments on this subject, as they appear to have been undertaken with great care.^f

Subsulphuret of Iron. One part of very fine sheet iron almost entirely free from carbon, mixed with three parts of pure sulphur, was slowly heated to redness in a glass retort with a luted receiver. The iron when cold retained its form, but was covered with greenish shining scales which readily peeled off. These scales were the subsulphuret of iron, which was still magnetical when pulverized. Two parts of these scales digested in nitro-muriatic acid, till dissolved, gave with muriated barytes 5.38 parts of sulphat of barytes. Estimating the acid of 100 parts of this sulphat at 34, and the sulphur of this 34 at 13.797, the 5.38 give 0.742 of sulphur (or 37.1 per cent.) in the subsulphuret. The supernatant liquor gave with ammonia 1.82 of peroxyd of iron, equal to 1.26 of metallic iron, and $1.26 + 0.742 = 2.002$, so that there is an excess of .002 over the sulphuret analyzed.

The composition of this subsulphuret of iron may therefore be taken at

Sulphur	37.	—	58.75
Iron	63.	—	100.00
	100		158.75

Supersulphuret of Iron. The purest crystallized iron pyrites was taken as the best specimen of this compound. It was examined by being first roasted on a platina plate, under a muffle, till all the sulphur was expelled, and the iron converted to red oxyd. Deducting the proportion of metallic iron in the sulphuret from that of the red oxyd, and estimating the rest of the pyrites as sulphur, (abstracting a small proportion of silex which remained after dissolving the red oxyd in muriatic acid) the composition of the pure supersulphuret of iron will give almost exactly a double portion of sulphur to

that in the subsulphuret, being actually found to consist of

Sulphur	53.92	—	117
Iron	46.08	—	100
	100.00		217

If the sulphur were 117.5 to 100 of iron the proportion would be exactly double that of the subsulphuret.

Though these proportions are very well defined, it appears that there may be several intermediate degrees of sulphuration of iron when prepared artificially, which may be partly owing to a mere solution of iron in sulphuret of iron, that may probably take place to an indefinite extent, and independent of true chemical combination.

Iron and Oxygen. Few parts of analytical chemistry have been so much attended to as the different degrees of oxygenation of iron, but the discordance between the results of several chemists (which is not trifling considering the pains taken) shews the difficulty of the subject. Berzelius has shewn in a very satisfactory manner that in most kinds of iron a new element must be taken into account, namely, *Silicium*, which is obtained from the siliceous part of the flux employed in the reduction of iron ores, and alloys the iron. See the article *SILICIUM* in this Appendix. The same eminent chemist has also shewn the difficulty (hitherto almost insuperable) of ascertaining the carbon in all manufactured iron with absolute accuracy, owing to the conversion of a portion of it into a volatile black oily matter which mixes with the hydrogen gas obtained during the solution of iron. Therefore whenever a given portion of the purest iron is converted into oxyd, to ascertain the elements of this oxyd a certain allowance must be made for the carbon which always is present, and for the silicium which is generally present, and appears in the form of silex after the action of acids.

The peroxyd or red oxyd of iron is the only one in whose composition the results of various chemists agree with tolerable accuracy, though even in this there is too much discordancy.

The peroxyd is thus composed, according to Berzelius' average results, on an analysis in which the carbon and silex are attended to.

Iron	69.34	—	100.00
Oxygen	30.66	—	44.25
	100.00		144.25

^f An. Chem. tom. 78.

Suboxyd of Iron and Black Oxyd. It has been advanced by Proust, and pretty generally allowed, that there are only two oxyds of iron, viz. the red and the black. The red is the peroxyd just described, and is without question the highest known state of oxygenation of this metal. It is equally certain that a definite oxyd of inferior degree exists, to which the name of black oxyd may be given; but there is a good deal of reason to conjecture the existence of a third oxyd, still lower in its proportion of oxygen, to which therefore the term *Suboxyd* is more properly applicable. Thenard has attempted to establish the existence of this oxyd, and we shall also find that the hypothesis of definite proportions (explained in the article *Affinity* in this Appendix) renders this still more probable, as it will correspond to an oxyd consisting of an atom of iron to an atom of oxygen, the black oxyd being two atoms of oxygen to one of iron, and the red oxyd three atoms of oxygen to one of iron. We shall however drop the consideration of this lowest oxyd, and only mention the *Black Oxyd*, *Suboxyd*, or *Oxidulum of Iron*, as commonly received.

This black oxyd is the base of the *Green Sulphat of Iron*, and its elements have been estimated by Buckholz, at 23 oxygen in 100 of oxyd, or 29.88 oxygen on 100 of metal. Berzelius analyzed this in the following way: some green sulphat of iron was made by dissolving sulphuret of iron in dilute sulphuric acid, crystallizing the salt and washing it with alcohol, to separate the adhering liquor, and drying it in a moderate warmth on blotting paper. Ten parts of this crystallized salt were heated by themselves in a retort, in a heat below redness, by which 4.63 parts of water were expelled. The heat was then raised to redness, till all the sulphuric acid was driven off, during which the oxyd passed to the state of red oxyd, which weighed 2.82, equal to 1.95 metallic iron. The sulphuric acid in 10 parts of this salt had been found by a previous experiment with a barytic salt, to amount to 2.842, so that the acid, the iron, and the water together, amounted to 9.422, leaving 0.578 for the oxygen combined with the iron; which gives an oxydation of 29.6 oxygen to 100. of iron, or very nearly the same as that given by Richter. As 29.5 of oxygen will exactly accord with a definite proportion, this number may be assumed without much error, and therefore the black oxyd of iron will consist of

Iron	77.22	—	100.00
Oxygen	22.78	—	29.5
	100.00		129.5

Therefore the oxygen of the black oxyd is to that of the red oxyd as $1:1\frac{1}{2}$ to a given quantity of iron; for $29.5 \times 1\frac{1}{2} = 44.25$.

If a lower degree of oxydation of iron is found, it may be expected to be in the proportion of 14.75 of oxygen to 100. of iron, and then the black oxyd will contain two proportions of oxygen, or $14.75 \times 2 = 29.5$, and the red oxyd, three proportions, or $14.75 \times 3 = 44.25$.

But M. Gay Lussac is stated to have lately given a memoir on the subject of the oxyds of iron, in which, as we learn from a short extract,* he shews the existence of three distinct oxyds, but instead of finding a lower degree than that of the black oxyd just described, he states an intermediate oxyd between this and the red oxyd. As we have not the particulars of the experiments, we shall only mention that the three oxyds have respectively to 100. of iron 28.3, 37.8, and 42.31 of oxygen. The lowest of these, which he terms *white oxyd*, he states to be obtained when iron decomposes water by the assistance of acids, but without the acid itself being changed, as when iron is dissolved in dilute sulphuric or muriatic acid. It is the base of the green sulphat of iron. The solutions of this oxyd are precipitated white by fixed alkalies, and by prussiat of potash; ammonia dissolves it copiously. The next oxyd, or that of 37.8 oxygen, is produced when iron is burnt in oxygen gas, or when water alone is decomposed over red hot iron. It is called here the *black oxyd*. This oxyd is separated of a deep brown by alkalies, or of a green, when much diluted. It is very magnetical, gives blue precipitates with the prussiate, and a black with galls, is soluble in ammonia though less than the last mentioned oxyd, and also in the supercarbonated alkalies. The next oxyd is the saturated or *red oxyd* of 42.31 oxygen, universally known, and is best obtained by passing vapours of nitric acid over iron. When the middle of these three oxyds (or black oxyd according to the author) is dissolved in sulphuric acid, and the solution crystallizes, the crystals are the green sulphat, the base of which is the white oxyd, and red sulphat remains in solution, so that the oxygen of the black oxyd divides unequally, and both a higher and lower oxyd are produced.

* Ann. Chem. tom. lxxx. p. 163.

The particulars of this memoir will doubtless be highly interesting. We may observe that these numbers expressing the degrees of oxydation, do not very much deviate from a proportion in which the common divisor is 7.07, in which case the white oxyd would contain 4 proportions (28.28), the black oxyd 5 proportions

(35.35), and the red oxyd 6 proportions (42.42).

At all events the concurring experiments of all later enquirers seem to prove at least two oxyds of iron, one of which consists of about 28. oxygen to 100 of metal, and the other (which is the red or peroxyd) contains $1\frac{1}{2}$ this proportion, or about 42 oxygen to 100 of metal.

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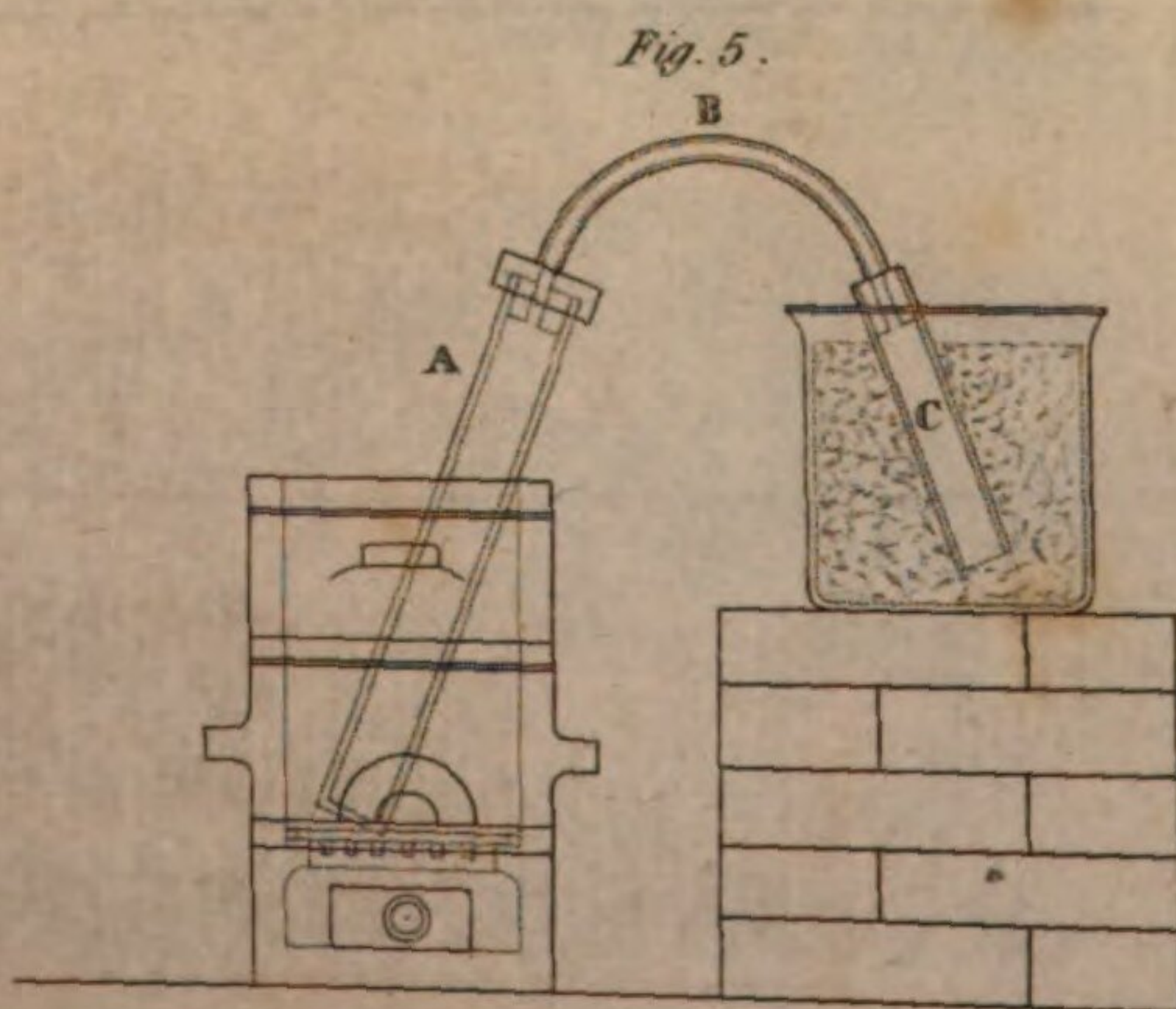
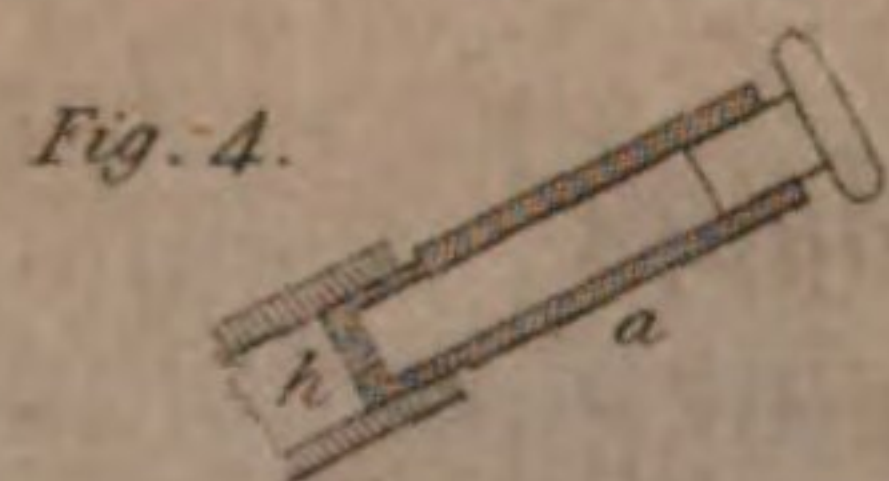
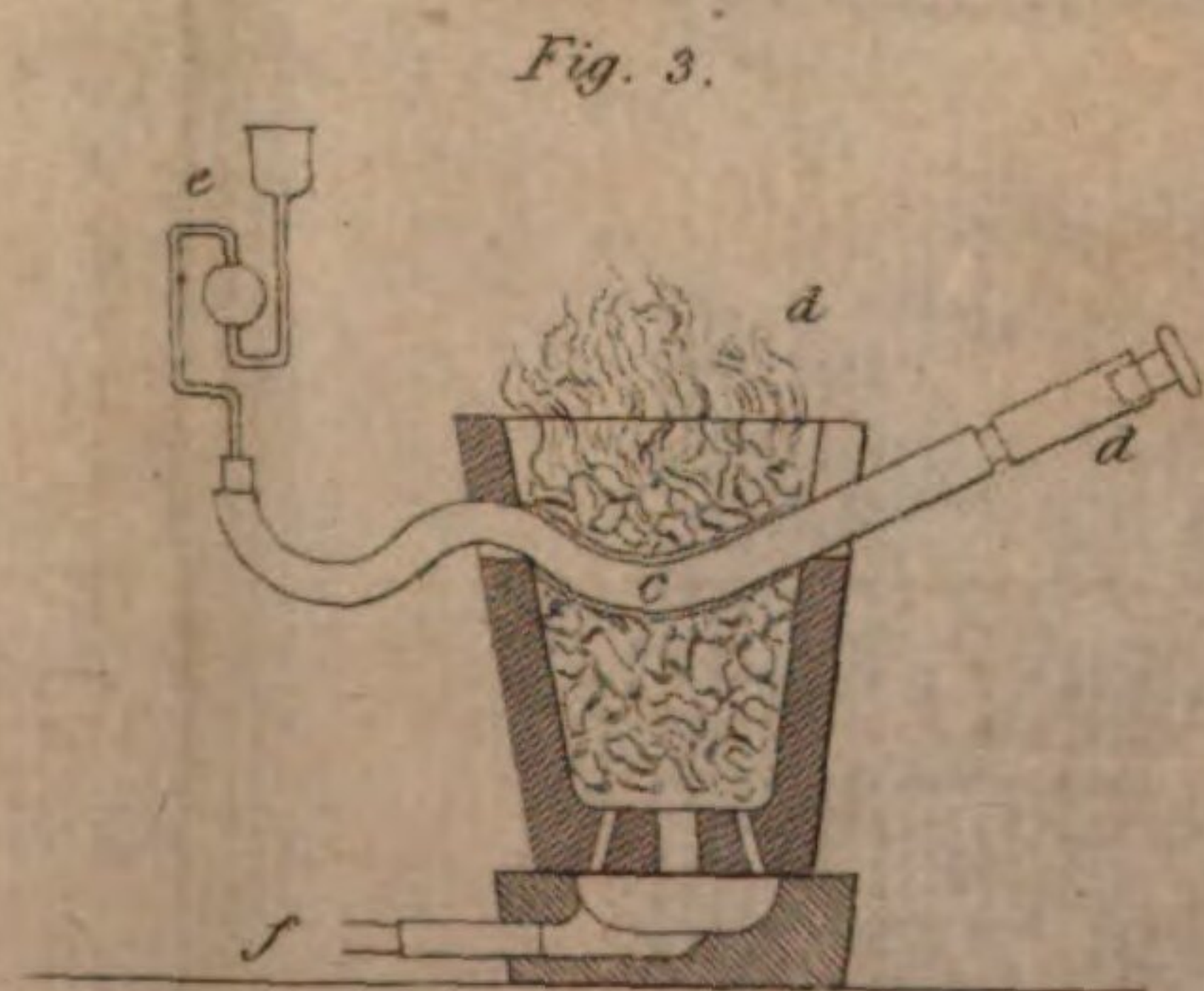
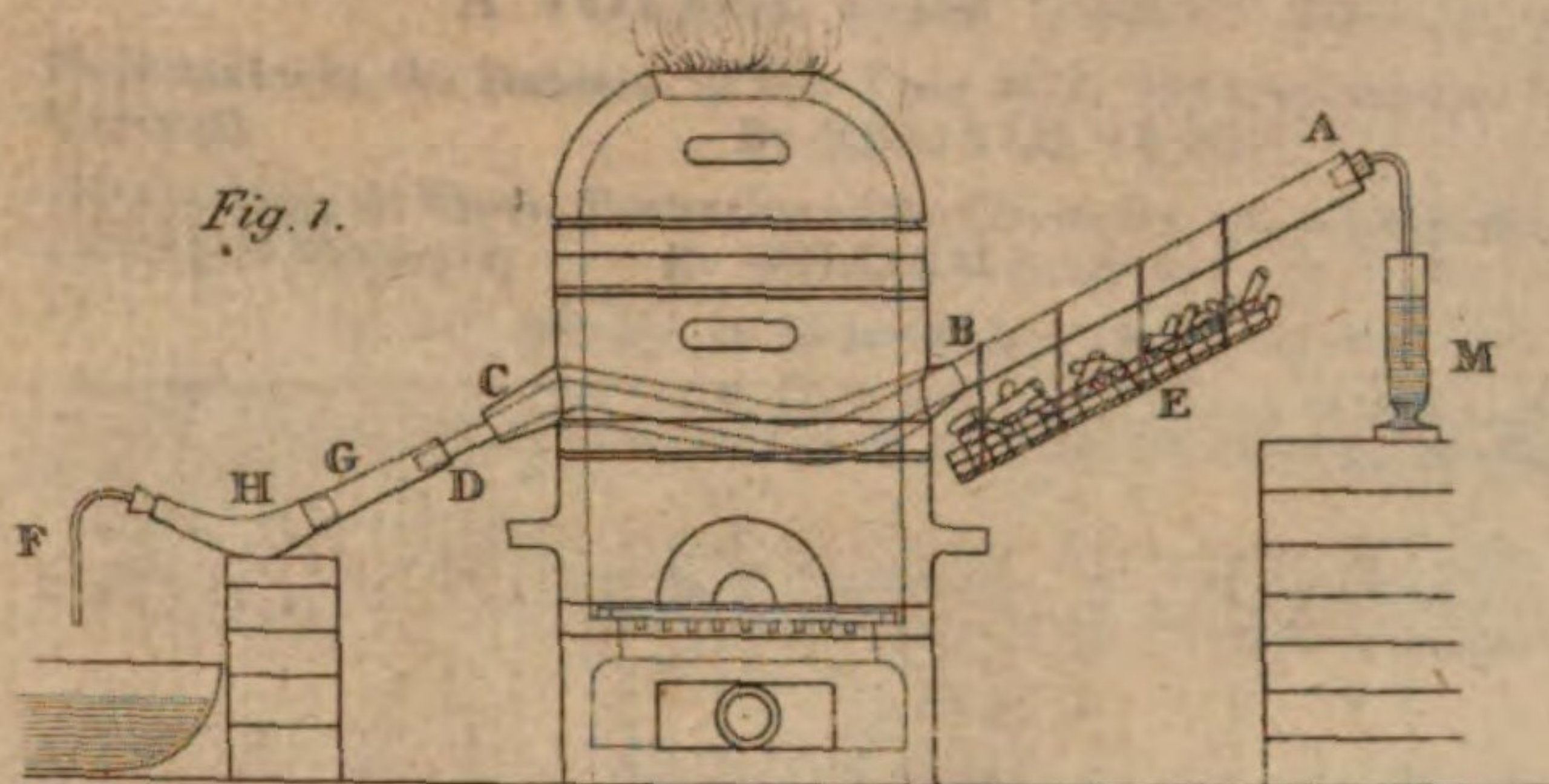
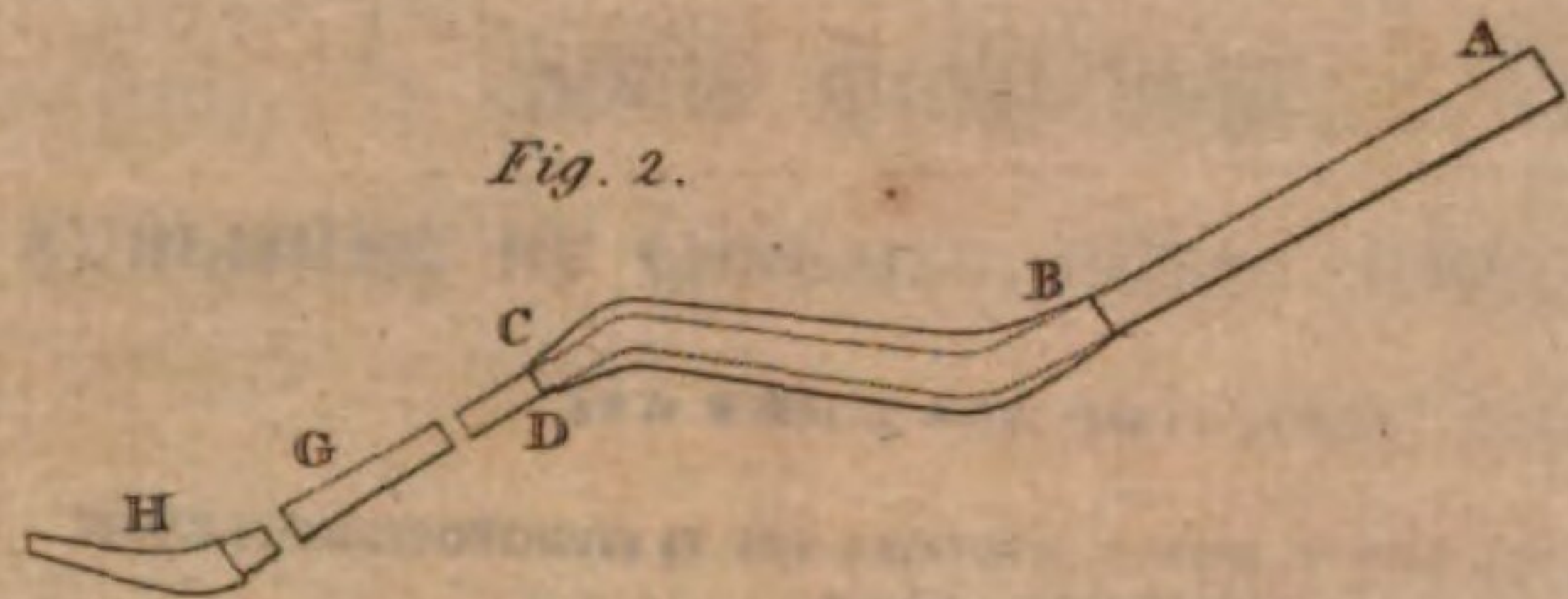
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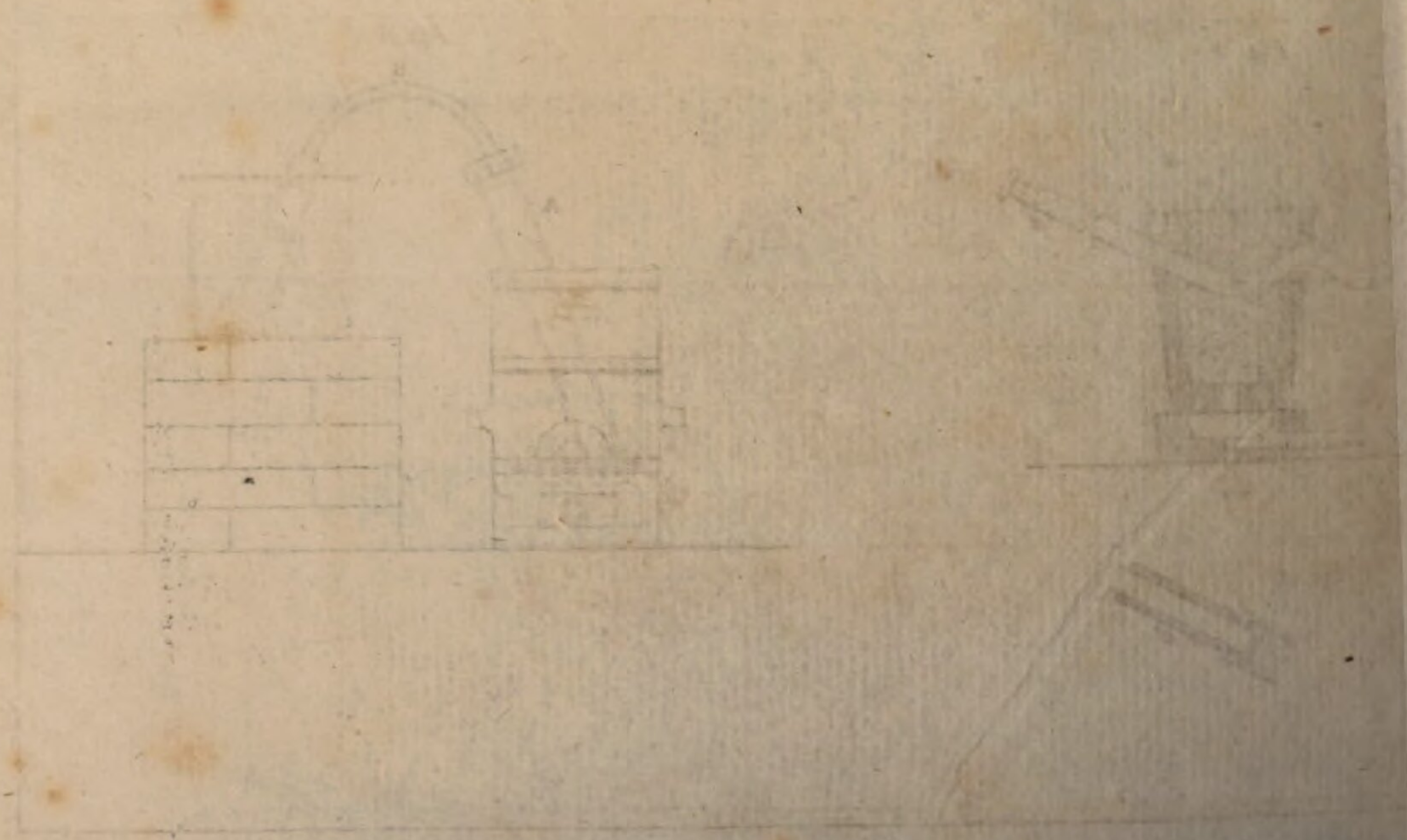
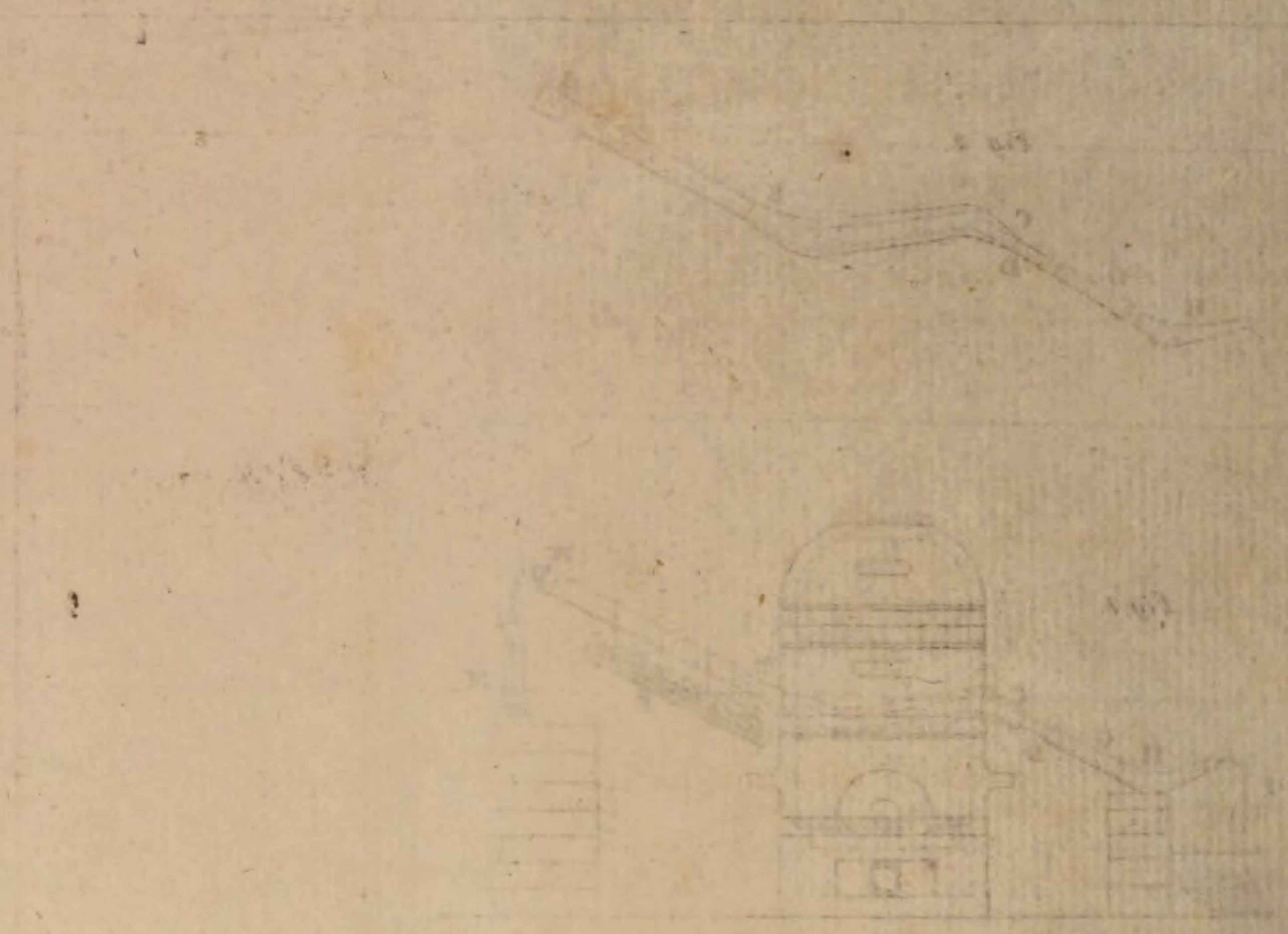
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